

AN INVESTIGATION OF THE RADIONUCLIDES  
OF ARSENIC PRODUCED BY CYCLOTRON  
BOMBARDMENT OF GERMANIUM WITH  
15 MEV DEUTERONS

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HARRY J. WATTERS  
AND  
JOHN F. FAGAN, JR.

Thesis  
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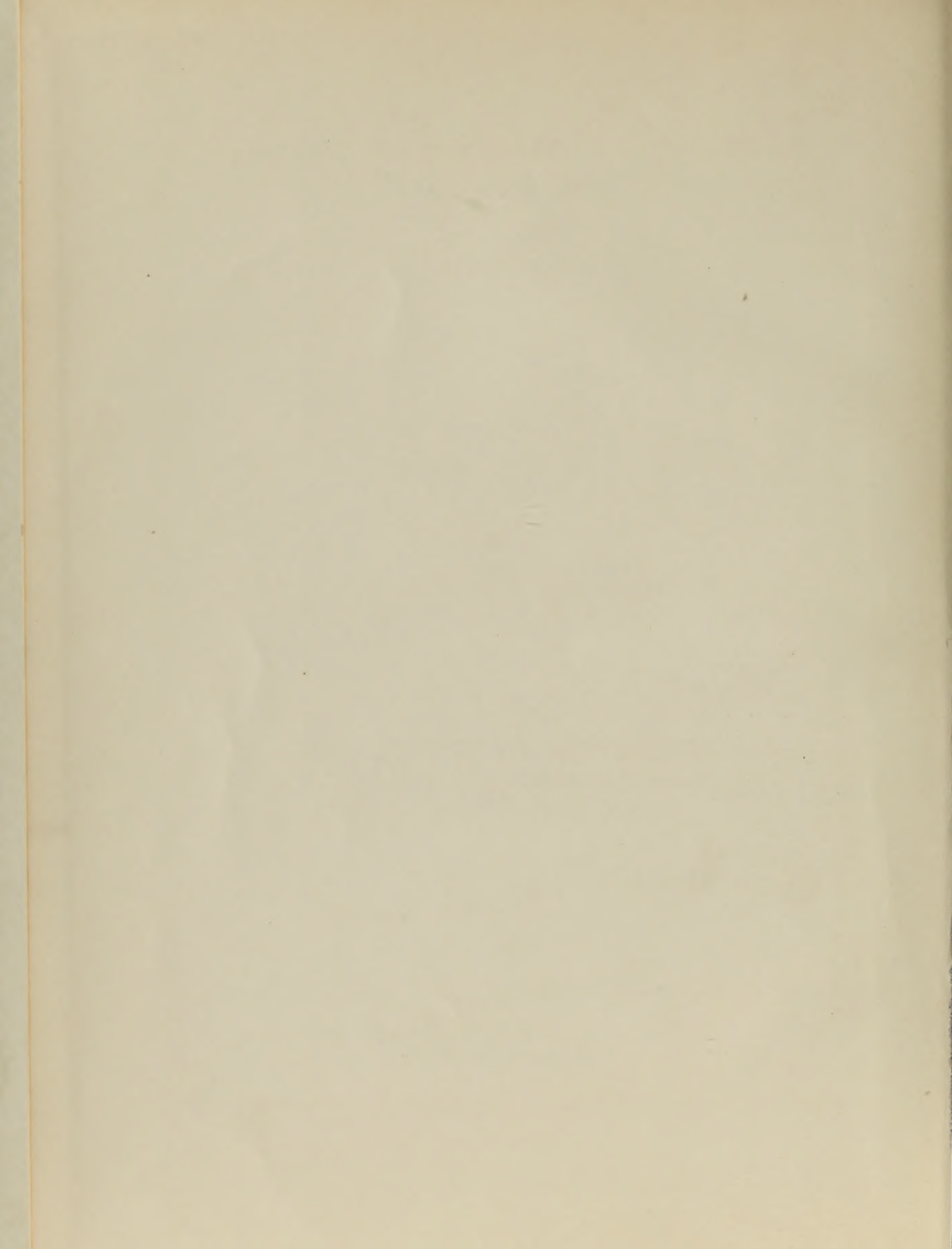
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PRODUCED BY CYCLOTRON BOMBARDMENT OF GERMANIUM

with  
15 Mev DEUTERONS

by

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SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF  
MASTER OF SCIENCE







**ABSTRACT**

The arsenic produced by a deuteron bombardment of germanium has been studied. The mixture contains the nuclides present in the mixture. Identification of isotopes was made by comparing measured values of half life and maximum  $\beta$  energy with the accepted values. Yield values were determined for each isotope present by  $4\pi$  solid angle

**Title: "An Investigation of the Radionuclides of Arsenic Produced by Cyclotron Bombardment of Germanium with 15 Mev Deuterons"**

**Authors: Harry J. Watters, Lieutenant Commander, U.S. Navy B. S., Purdue University (1949)**

and **John F. Fagan, Jr., Lieutenant, U. S. Navy B. S., U. S. Naval Academy (1945)**

The  $4\pi$  solid angle counter constructed was shown to have an efficiency of very nearly 100 percent for particles which escape the source. This counter has proven to be a

very practical laboratory instrument and detailed instructions for its use are included as an appendix. Submitted to the Department of Physics on May 25, 1953 in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

Title: "An investigation of the Radioactivity of Arsenic  
Produced by Cyclotron Bombardment of Germanium  
with 15 Mev Deuterons"

Author: Harry J. Watson, Lieutenant Commander, U.S. Navy  
B. S., Purdue University (1943)

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B. S., U. S. Naval Academy (1945)

Submitted to the Department of Physics on May 25,  
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The arsenic produced by a deuteron bombardment of germanium has been studied to determine the nuclides present in the mixture. Identification of isotopes was made by comparing measured values of half life and maximum  $\beta$  energy with the accepted values. Yield values were determined for each isotope present by  $4\pi$  solid angle counter measurements.

Counting rates were measured for a period of 53 days with  $4\pi$  and coincidence counters, obtaining half lives which indicated that the nuclidic mixture was made up of  $As^{71}$ ,  $As^{72}$ ,  $As^{73}$ ,  $As^{74}$ , and  $As^{77}$ . These indications were confirmed by maximum  $\beta$  energy values obtained by absorption measurements and from  $\gamma$  energies found using a  $\gamma$ -ray scintillation spectrometer. Measurements indicated that the 40 hour half life reported for  $As^{77}$  is in error by a significant amount, and that no  $As^{76}$  was obtained by this bombardment.

The  $4\pi$  solid angle counter constructed was shown to have an efficiency of very nearly 100 percent for particles which escape the source. This counter has proven to be a very practical laboratory instrument and detailed instructions for its use are included as an appendix.

The census prepared by a German Government by  
Germany has been studied as containing the earliest  
present in the history. Identification of languages was  
made by comparing various words of both life and death  
and a study of the various values. This value was  
determined for each language present by the value of the

The following table shows the results of the tests conducted on the various specimens of the material under consideration. The specimens were subjected to a series of tests, including tensile, compression, and impact tests, and the results are given in the table below.

There is no other person mentioned in the report.



The following is a tabular summary of the results of the investigation:

Isotope	Method of decay	Energy (MeV)	$T_{1/2}$	Thick target yield* (uc/μamp-hr)
As <sup>71</sup>	β <sup>+</sup>	0.66	48.2 ± 1.2 hrs.	7.6
As <sup>72</sup>	β <sup>+</sup>	3.25	25.8 ± 0.2 hrs.	64.9
	γ	0.85		
As <sup>73</sup>	β <sup>-</sup> 0.11 > E <sub>max</sub> > 0.02		99.9 ± 9.2 days	1.1
As <sup>74</sup>	β <sup>+</sup>	0.99, 1.49	17.82 ± 0.13 days	5.2
	β <sup>-</sup>			
As <sup>76</sup>	Not present in the mixture			
As <sup>77</sup>	β <sup>-</sup>	< 0.7	> 70 hours	5 < yield < 15**

\* The thick target yield values specified apply if the deuteron beam current was exactly 36 μamps and if the arsenic separation efficiency was 100 percent. Yield values quoted are based on β counting only and do not include orbital electron capture.

\*\* Based on ratios of total β to β<sup>+</sup> counting rates.

Thesis Supervisor: Robley D. Evans

Title: Professor of Physics

The following is a partial summary of the results of the investigation:

Location of dam	Time of day	Time of day	Time of day	Time of day
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$
$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$	$10^{\circ}$

See Appendix for details

The above table gives a summary of the results of the investigation. It shows that the results are in good agreement with the theoretical predictions. The results are also in good agreement with the results of other investigators.

See Appendix for details of the investigation.

TABLE  
Professor of Physics

## ACKNOWLEDGMENTS

The authors wish to express sincere thanks to their thesis advisor, Professor Robley D. Evans, for his interest and advice during the course of this work. Grateful acknowledgment is also made to Doctor Gordon L. Brownell, who suggested the problem, for his constant guidance and for the opportunity to utilize the facilities of the Massachusetts General Hospital Research Laboratory.

Thanks are due to all members of the group in the Radioactivity Center for their interest and suggestions. The opportunity for graduate study provided by the Radioactivity Center and its sponsors is greatly appreciated.

The subject also in various places in the text is mentioned, but it is not clear from the text whether it is a separate subject or a continuation of the previous one. The text is very faint and the words are difficult to read.



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## I. INTRODUCTION

### A. Importance of the Investigation

The fact that tumors of the brain take up a large amount of trace metal compared with that taken up by normal brain tissue makes it possible to detect and to actually determine the location of tumors in the human brain. Under the supervision of Dr. Gordon L. Brownell, a group at the Research Laboratory of the Massachusetts General Hospital has developed a suitable tracer technique for the diagnosis and preoperative location of brain tumors, using positron emitting isotopes. After intravenous injection of the tracer material, the patient's head is mechanically scanned in two dimensions by two scintillation counters connected in coincidence. Third dimensional location is obtained from the unbalanced single channel counting rates of the separate counters.

Since January 1953 a large number of patients have been examined using this technique. The results are

2025/2026/2027 and 2028/2029

The following is a list of the names of the persons who have been appointed to the various positions in the Department of the Interior, for the year 1900.

outstanding. From many cases clinically diagnosed as borderline, the presence or absence of neoplastic brain tissue has been determined by this method. In all cases where surgery was performed, tumor location obtained by this technique has been confirmed. As yet no known incorrect diagnoses have been made. In addition to providing more quantitative information than is available from clinical diagnosis, this method provides the left-to-right localization which is difficult and often impossible to obtain clinically.

Radioactive arsenic was selected as the tracer metal because of several considerations. Arsenic is readily available from a deuteron bombardment of germanium. The half lives of arsenic isotopes fall within an acceptable range for tracer utilization. Most of the  $\gamma$ -rays emitted from arsenic isotopes are soft, thus decreasing harmful biological effects due to radiation. A very important advantage is that a large percentage of arsenic activity consists of positron emission. Precision measurements with very high resolution may be made on the resulting annihilation radiation.

The tracer arsenic is not injected until several days after bombardment. During this period any short-



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lived activity present decays to a negligible value compared with that of the 17.5 day isotope<sup>(11,13)</sup> and does not affect the scanning measurements which require a period of approximately two hours. If the half lives and the relative activity percentages of the short-lived isotopes were accurately known, this waiting period could be decreased or even eliminated with a resultant increase in useful activity obtained from a given bombardment.

The purpose of the present investigation is to determine insofar as possible the methods of decay and associated decay energies, half lives, absolute activities, and isotopic yields of the arsenic obtained by the deuteron bombardment of germanium. In addition to decreasing the delay between bombardment and injection, this information may permit the use of short-lived isotopes as tracers. In effect this also decreases the bombardment time required to obtain a given amount of tracer material. It may be desirable to examine a single patient several times over a period of a few weeks. Accurate knowledge of the short-lived activity present may permit frequent injections of a lesser amount of tracer solution while avoiding harmful effects from the chemical toxicity of carrier arsenic present.

(11.11)

and does not affect the economic consequences which  
result from the fact of the existence of the  
half lives and the relative activity percentages of  
the short-lived isotopes with respect to the  
waiting period could be increased by even eliminating  
also a significant increase in total activity obtained  
from a given quantity.

[illegible]

## B. Results of Previous Investigations

Prior to Sagane's investigations in 1938<sup>(1)</sup> very little was known about the radionuclides of arsenic. The principal results of his work on the arsenic produced by a deuteron bombardment of germanium, as modified by others, are tabulated below and include all data reported through 1941.

<u>Isotope</u>	<u>Type radiation</u>	<u>Energy (Mev)</u>	<u>Half life</u>	<u>Reference</u>
As <sup>71</sup>	$\beta^+$	0.08	50 hour	2, 4
As <sup>73</sup>	$\beta^+$	0.08	66 min	2, 4
As <sup>74</sup>	$\beta^+$	0.9	10 day	1, 4
As <sup>76</sup>	$\beta^-$	1.1	26.8 hour	3, 5, 6
		1.7		
		2.7		
	$\gamma$	1.5		
		2.2		
		2.8	55-80 day	1, 2, 4
As <sup>77</sup>	$\beta^-$			
As <sup>78</sup>	$\gamma$	0.27	66 min	7

Very little new information was published for several years but commencing in 1948 results were published which



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Answers to the questions are given in the answers section.

and the results of the study are discussed.

is, ultimately, to understand ourselves a bit better.

CONTACT FOR MORE INFORMATION AND REQUESTS FOR MATERIALS

\* 1971 August 22 - February 23 Feb 22

Location	Time	Depth	Temperature	Remarks
1. 10	10:00	10.0	10.0	10.0
2. 10	10:10	10.0	10.0	10.0
3. 10	10:20	10.0	10.0	10.0
4. 10	10:30	10.0	10.0	10.0
5. 10	10:40	10.0	10.0	10.0
6. 10	10:50	10.0	10.0	10.0
7. 10	11:00	10.0	10.0	10.0
8. 10	11:10	10.0	10.0	10.0
9. 10	11:20	10.0	10.0	10.0
10. 10	11:30	10.0	10.0	10.0
11. 10	11:40	10.0	10.0	10.0
12. 10	11:50	10.0	10.0	10.0
13. 10	12:00	10.0	10.0	10.0
14. 10	12:10	10.0	10.0	10.0
15. 10	12:20	10.0	10.0	10.0
16. 10	12:30	10.0	10.0	10.0
17. 10	12:40	10.0	10.0	10.0
18. 10	12:50	10.0	10.0	10.0
19. 10	13:00	10.0	10.0	10.0
20. 10	13:10	10.0	10.0	10.0
21. 10	13:20	10.0	10.0	10.0
22. 10	13:30	10.0	10.0	10.0
23. 10	13:40	10.0	10.0	10.0
24. 10	13:50	10.0	10.0	10.0
25. 10	14:00	10.0	10.0	10.0
26. 10	14:10	10.0	10.0	10.0
27. 10	14:20	10.0	10.0	10.0
28. 10	14:30	10.0	10.0	10.0
29. 10	14:40	10.0	10.0	10.0
30. 10	14:50	10.0	10.0	10.0
31. 10	15:00	10.0	10.0	10.0
32. 10	15:10	10.0	10.0	10.0
33. 10	15:20	10.0	10.0	10.0
34. 10	15:30	10.0	10.0	10.0
35. 10	15:40	10.0	10.0	10.0
36. 10	15:50	10.0	10.0	10.0
37. 10	16:00	10.0	10.0	10.0
38. 10	16:10	10.0	10.0	10.0
39. 10	16:20	10.0	10.0	10.0
40. 10	16:30	10.0	10.0	10.0
41. 10	16:40	10.0	10.0	10.0
42. 10	16:50	10.0	10.0	10.0
43. 10	17:00	10.0	10.0	10.0
44. 10	17:10	10.0	10.0	10.0
45. 10	17:20	10.0	10.0	10.0
46. 10	17:30	10.0	10.0	10.0
47. 10	17:40	10.0	10.0	10.0
48. 10	17:50	10.0	10.0	10.0
49. 10	18:00	10.0	10.0	10.0
50. 10	18:10	10.0	10.0	10.0
51. 10	18:20	10.0	10.0	10.0
52. 10	18:30	10.0	10.0	10.0
53. 10	18:40	10.0	10.0	10.0
54. 10	18:50	10.0	10.0	10.0
55. 10	19:00	10.0	10.0	10.0
56. 10	19:10	10.0	10.0	10.0
57. 10	19:20	10.0	10.0	10.0
58. 10	19:30	10.0	10.0	10.0
59. 10	19:40	10.0	10.0	10.0
60. 10	19:50	10.0	10.0	10.0
61. 10	20:00	10.0	10.0	10.0
62. 10	20:10	10.0	10.0	10.0
63. 10	20:20	10.0	10.0	10.0
64. 10	20:30	10.0	10.0	10.0
65. 10	20:40	10.0	10.0	10.0
66. 10	20:50	10.0	10.0	10.0
67. 10	21:00	10.0	10.0	10.0
68. 10	21:10	10.0	10.0	10.0

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conflicted with much of the previous data. The following is a tabulation of the most reliable data now available on the radioisotopes of arsenic without regard to their method of activation:

Isotope	Type radiation	Energy (Mev)	Half life	Reference
$As^{70}$	$\beta^+$		82 min	9
$As^{71}$	$\beta^+$ (33%)	0.6	53-60 hour	10, 11, 12
	$\gamma$ (67%)	0.162		
$As^{72}$	$\beta^+$	0.27	26 hour	9, 11, 13
		0.67		
		1.84		
		2.5		
		3.34		
	$\gamma$	0.702		
		0.836		
$As^{73}$	$\gamma$	0.052	70-100 day	11
$As^{74}$	$\beta^-$	0.69, 1.36	17.5 day	11, 13
	$\beta^+$	0.92, 1.53		
	$\beta^-/\beta^+ \sim 1.0\%$			
	$\gamma$	0.593	27.6 hour	14, 16
$As^{76}$	$\beta^+/\beta^- \leq 0.07\%$			
	$\gamma$	0.55, 1.21	40 hour	15, 16, 20
$As^{77}$	$\beta^-$	0.679, 0.7		
	no $\gamma$			

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Location	Altitude	Temperature	Humidity	Wind	Clouds	Pressure	Time
1. Base	1000	25.0	60%	10	0	1013	0800
2. Summit	2000	15.0	40%	15	1	1010	0900
3. Ridge	1500	20.0	50%	12	0	1012	1000
4. Valley	800	28.0	70%	8	0	1014	1100
5. Plateau	1200	18.0	45%	10	1	1011	1200
6. Canyon	900	26.0	65%	10	0	1013	1300
7. Peak	2200	12.0	35%	18	2	1008	1400
8. Slope	1800	16.0	40%	15	1	1009	1500
9. Summit	2100	14.0	38%	16	1	1009	1600
10. Base	1000	24.0	55%	10	0	1012	1700

## II. NUCLEAR PROPERTIES TO BE MEASURED

Time and equipment limitations prohibited conducting an investigation which could determine actual decay schemes of the active material. With a desire to extract as much information as possible in the time available, attempts were made to determine the following for each isotope of arsenic obtained from the bombardments:

1. Absolute  $\beta$  activity.
2. Half life.
3. Maximum  $\beta$  energies.

In addition it was desirable to obtain information regarding the  $\gamma$ -energies of the mixture of isotopes and the variation of the spectrum with time.

## II. JOURNAL PRESENTATION OF THE REPORT

The first assignment in this course is to prepare a report on the investigation of the chemical reaction between hydrogen and oxygen. The report should be written in a clear and concise manner, and should include a description of the experiment, the results obtained, and a discussion of the results. The report should be written in a way that is easy to read and understand, and should be well organized and presented.

1. Introduction

2. Materials & Methods

3. Results

4. Discussion

5. Conclusion

6. References

7. Appendix



### III. EXPERIMENTAL PROCEDURE

#### A. Preparation of Radioactive Arsenic

A chip of pure germanium metal  $1/32$  inch thick with dimensions  $3/8$  inch by 1 inch was used as a target in the M.I.T. cyclotron. This chip was bombarded with 15 Mev deuterons for a period of 20 minutes with an average beam current of 30 pamps.

After bombardment the germanium metal was oxidized to  $\text{GeCl}_4$  in an evacuated system using gaseous  $\text{Cl}_2$ .

To this was added  $\text{HCl}$ ,  $\text{H}_2\text{O}_2$ , and arsenic carrier after which the bulk of the  $\text{GeCl}_4$  was distilled out. The arsenic remaining in the solution as  $\text{As}^{+5}$  was precipitated as a metal by the addition of ammonium hypophosphite. A detailed description of this separation procedure is contained in reference 21.

#### B. Schedule of Observations

Continuous observations were made of the disintegration rate of the active material by use of the 4 $\pi$  and coincidence counters. In an attempt to ascertain



whether or not the arsenic contained any positron-emitting isotopes having half lives of the order of 1 hour or less (2,3,17,23,24), coincidence counter measurements were made as follows: each minute during the third hour after bombardment, every 5 minutes during the fourth hour, every 10 minutes during the fifth hour, and every 15 minutes during the sixth hour. Thereafter the maximum interval between measurements was adjusted to approximately 1/10th the value of the half life indicated by a continuous plot of counting rate observations. *Schedule previously given.*

Due to the time required for preparation of 4π counter sources and the time involved in making absorption measurements with the end window β counter, observations with these instruments were made hourly from the 6th through the 17th hour after bombardment, and thereafter in accordance with the schedule outlined above.

Using the sodium iodide scintillation spectrometer described in Appendix II an initial scan of the energy spectrum up to 3 Mev was made within three hours after bombardment in order to determine the maximum energy γ-rays emitted from the arsenic. With no detectable γ-energies present greater than 1 Mev, an operating range

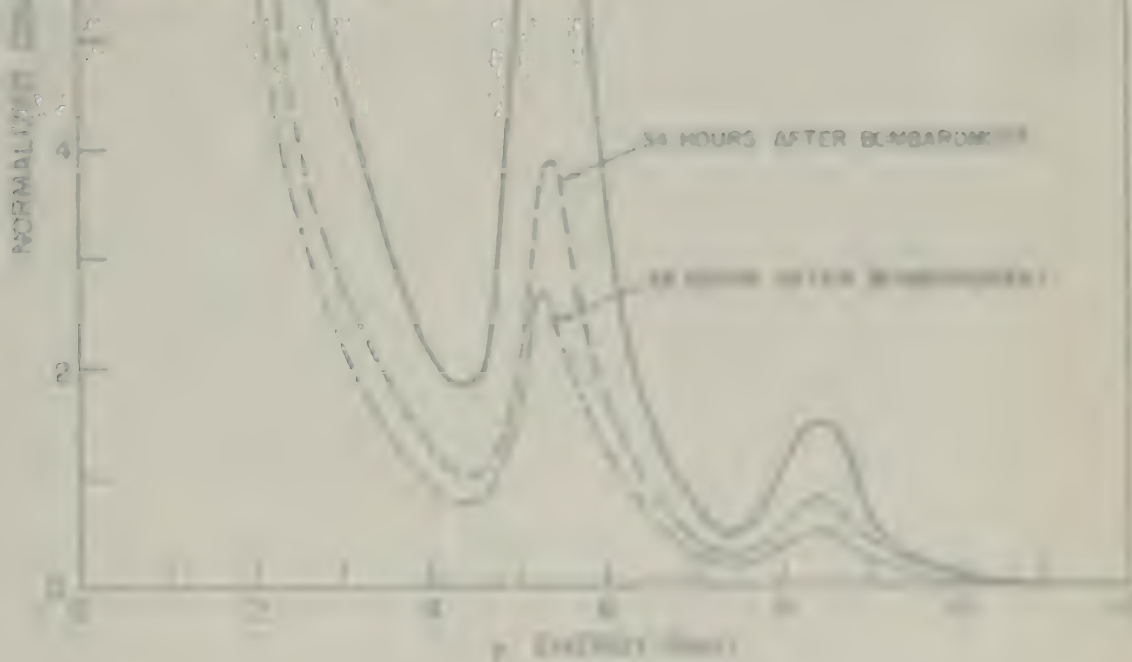


whether or not the results obtained are reliable.  
The following table shows the results of the work of I  
and my last (1918, 1919, 1920) experiments on the same  
points were made as follows: each animal being the  
same from one experiment to the next, every 2 weeks being  
the interval, every 10 minutes during the first hour,  
and every 15 minutes during the rest of the day. Therefore  
the medium interval between measurements was adjusted  
to approximately 1/10th the value of the half life  
indicated by a continuous plot of constant rate curves.  
Time.

For the first period the treatment of the  
animal before and the time involved in taking readings  
was constant with the animal's strength, observations  
were made at intervals of 10 and 15 minutes from the first  
reading. The first hour after treatment, and immediately  
in connection with the results obtained were:  
During the medium radio-activation experiments  
described in Appendix II an initial run of two weeks  
specimens up to 1 day was made with the same series of  
readings in order to determine the medium interval to  
be used from the results. With an interval of  
medium interval greater than 1 day, an increasing range

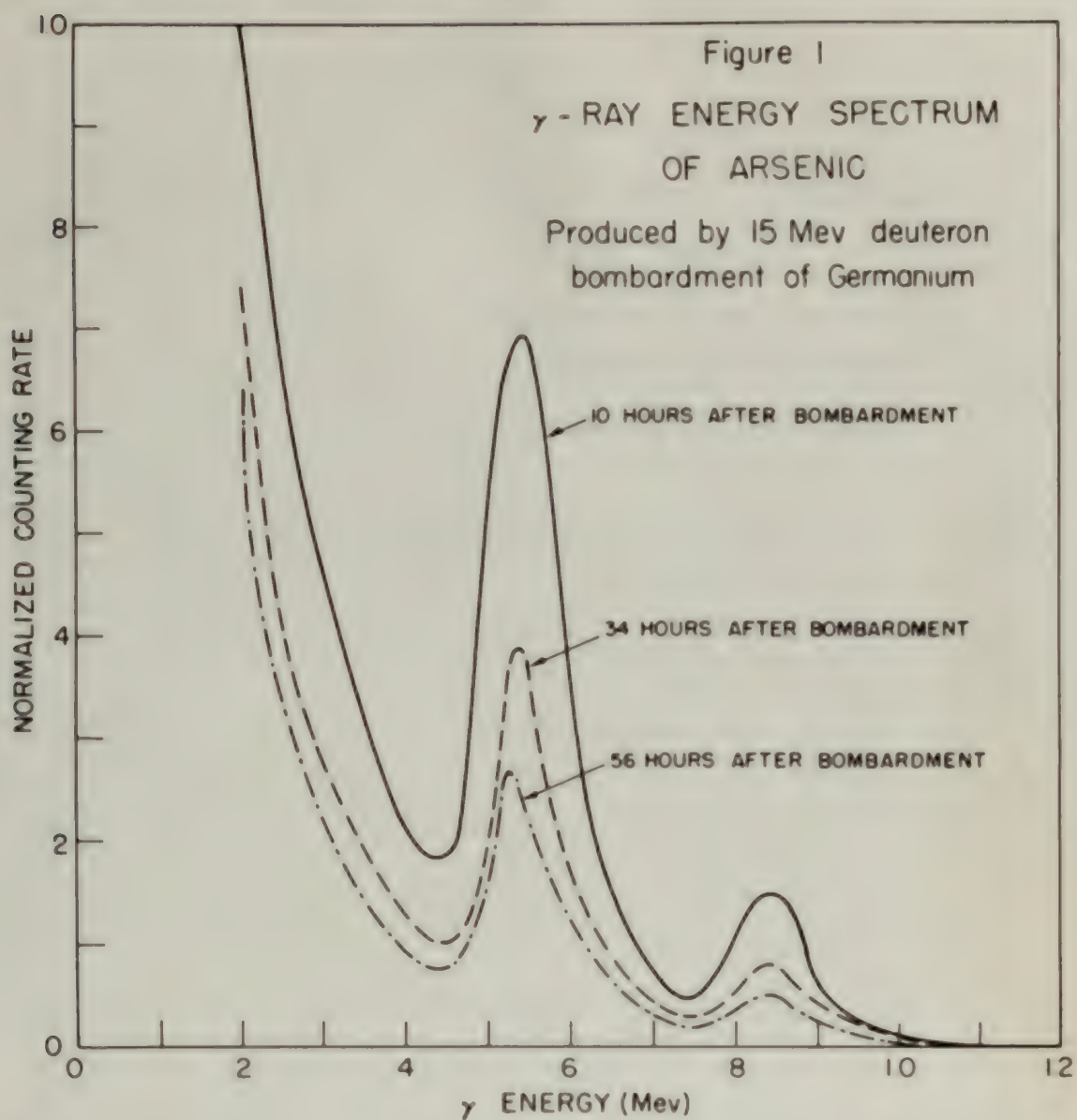
was chosen which included all  $\gamma$ -energies up to approximately 1.3 Mev. This energy range was scanned continually for the first 72 hours after bombardment (Fig. 1). The high energy range was scanned at intervals during this period with negative results. An additional energy spectrum was obtained 52 days after bombardment (Fig. 2) and as before, no high energy  $\gamma$ -rays were detectable.

Using the end window  $\beta$  counter, counting rates were measured for absorber thicknesses of from zero to 2526 mg/cm<sup>2</sup>. Observations were made in accordance with the time schedule previously given.

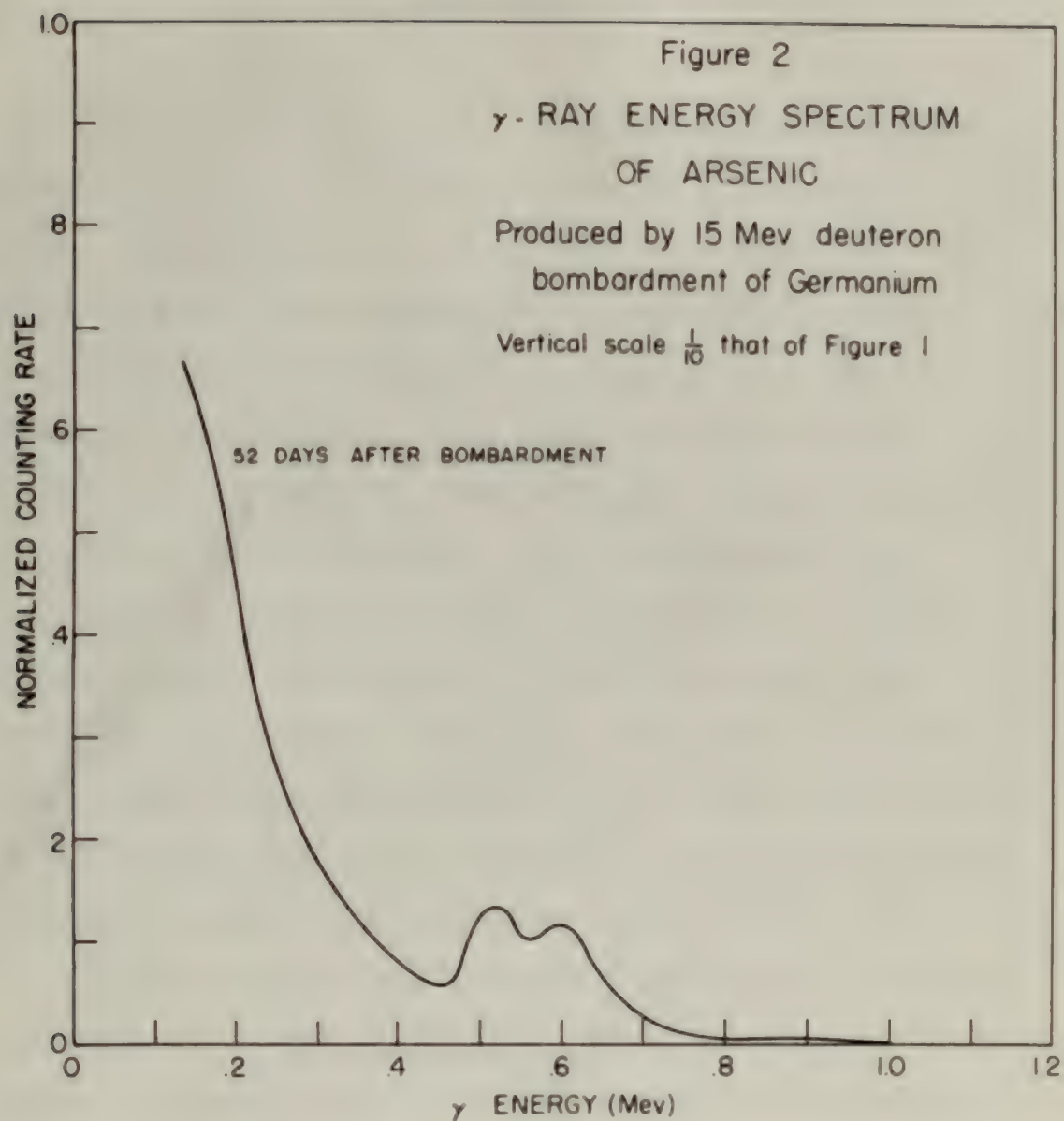




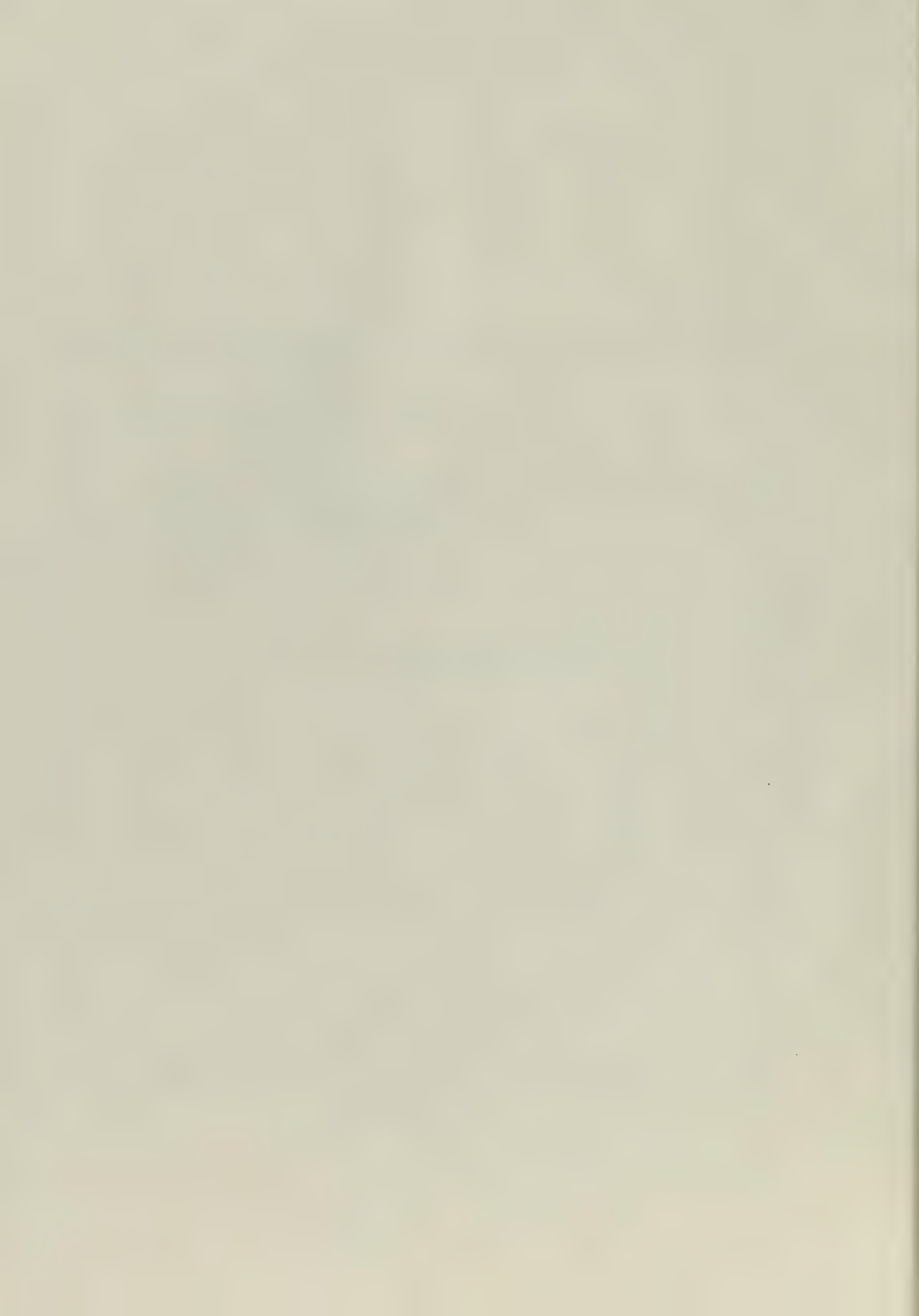












#### IV. METHODS USED IN INTERPRETATION OF DATA

---

##### A.) Half Life

Observed counting rate, corrected for instrumental error, was plotted on semilog paper as a function of time. Approximately 20 days after bombardment the curve obtained from coincidence measurements assumed a constant slope indicating the presence of a single isotope. Application of the method of least squares to data in the region of constant slope yielded a determination of half life, zero time activity, and their respective standard deviations. Subtraction of values thus obtained from the curve of total counting rate resulted in a residual curve also possessing a constant final slope. Successive application of this method permitted the resolution of 3 straight line components from the data obtained by coincidence counting (Fig. 3).

The 4 $\pi$  counter data included a relatively long-lived component which was not apparent in coincidence measurements. Assuming this to be As<sup>73</sup> reported as a 0.05 Mev

A. THE HISTORY

The history of the world is a long and complex one, and it is difficult to summarize it in a few words. However, it is possible to outline the major events and trends that have shaped the world as we know it today. The history of the world is a story of the human race, of its struggles, its achievements, and its progress. It is a story of the human mind, of its capacity for reason, its ability to create, and its desire for knowledge. It is a story of the human heart, of its emotions, its passions, and its yearning for love and happiness. The history of the world is a story of the human spirit, of its courage, its resilience, and its hope for a better future. The history of the world is a story of the human race, of its struggles, its achievements, and its progress. It is a story of the human mind, of its capacity for reason, its ability to create, and its desire for knowledge. It is a story of the human heart, of its emotions, its passions, and its yearning for love and happiness. The history of the world is a story of the human spirit, of its courage, its resilience, and its hope for a better future.



Figure 3

## COUNTING RATE VS TIME

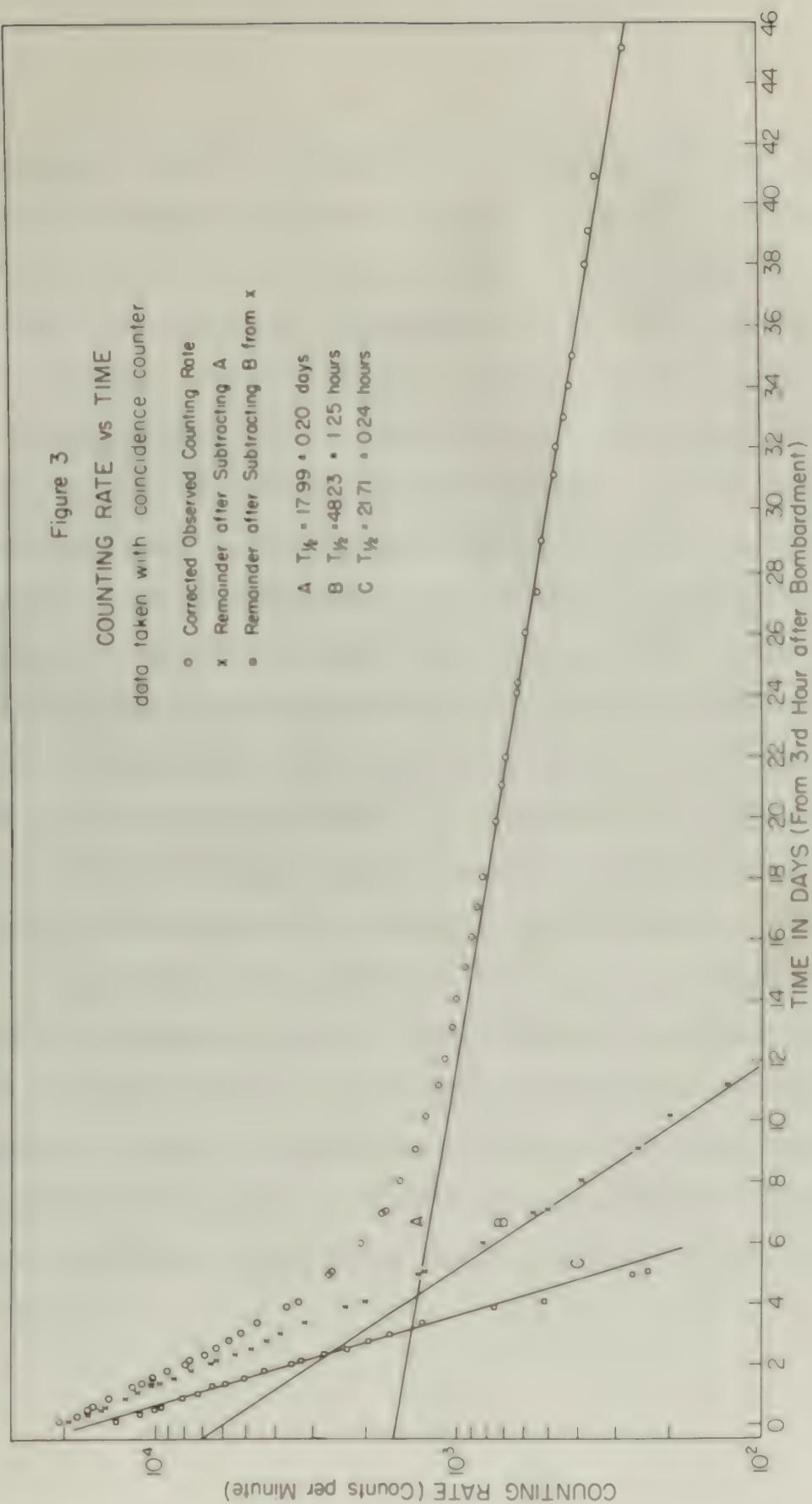
data taken with coincidence counter

- Corrected Observed Counting Rate
- x Remainder after Subtracting A
- Remainder after Subtracting B from x

$$A \quad T_{1/2} = 17.99 \pm 0.20 \text{ days}$$

$$B \quad T_{1/2} = 48.23 \pm 1.25 \text{ hours}$$

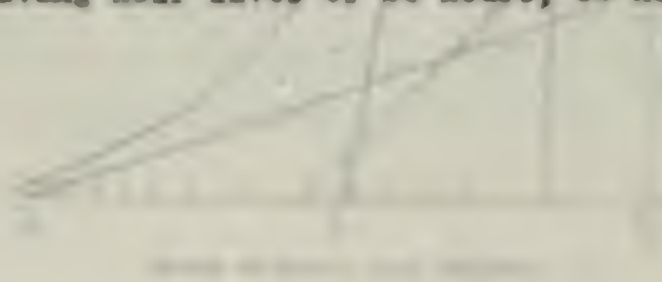
$$C \quad T_{1/2} = 21.71 \pm 0.24 \text{ hours}$$





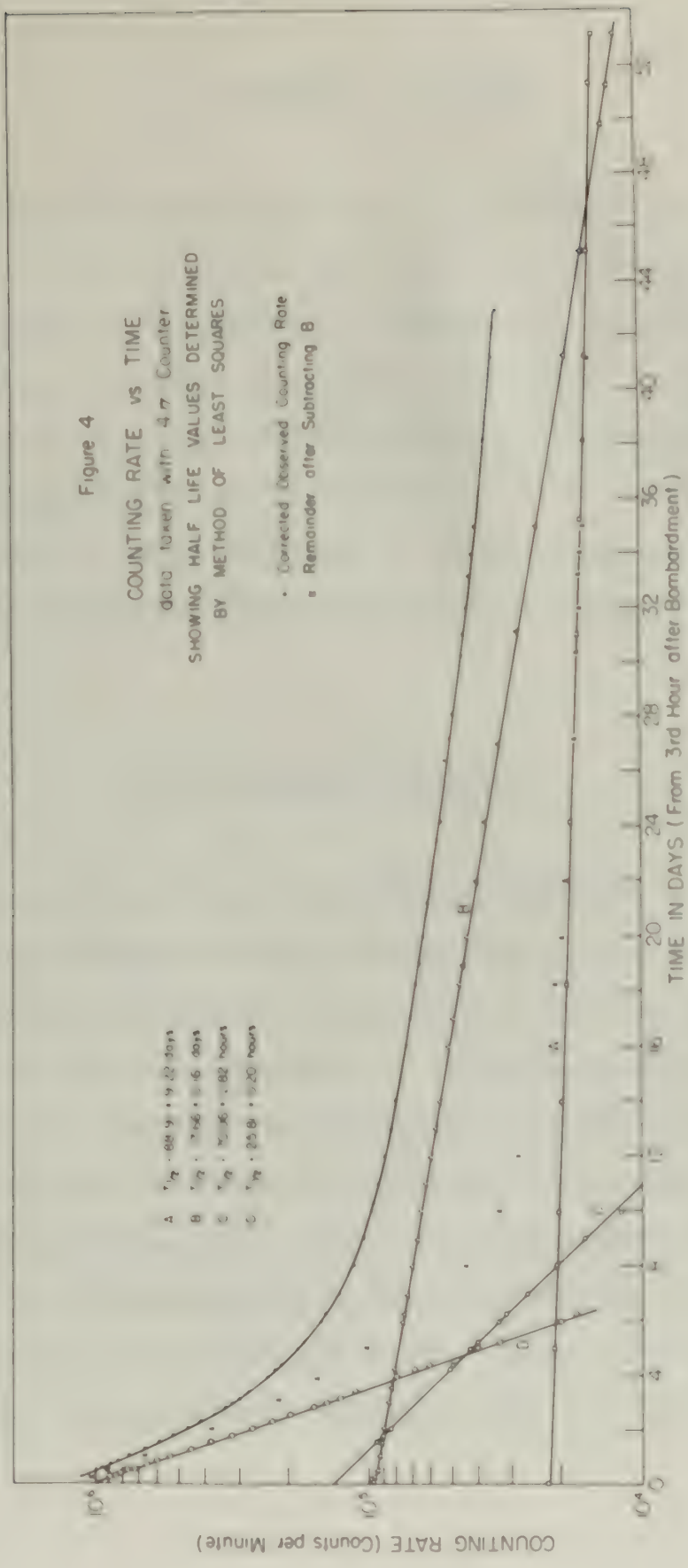
negatron emitter of half life  $\sim 80$  days, <sup>(10)</sup> one  $4\pi$  counter source was covered with  $13.7 \text{ mg/cm}^2$  of aluminum foil (a thickness equivalent to  $\sim 3$  times the range of a 0.05 Mev electron) commencing on the 41st day after bombardment. Data obtained with this source plotted as a straight line with a half life of 17.68 days. After subtraction of this 17.68 day activity from the total counting rate curve the constant slope extremity of the residual curve indicated a half life of  $\sim 80$  days. This procedure permitted early evaluation of data without waiting for the predominance of the 89 day component and the results are in good agreement with the  $\text{As}^{73}$  method of decay reported by Mel. <sup>(12)</sup> Successive application of the method of least squares to the  $4\pi$  counter data resulted in the resolution of 4 straight line components. (Fig. 4)

Half life determinations were also made from semilog plots of counting rate vs time obtained using absorbers of specific thickness with the end window  $\beta$  counter. The method of curve subtraction previously outlined was employed and a total of 3 straight line components were resolved having half lives of 26 hours, 53 hours, and 16.7 days.





negative effect of half life  $\sim 10^{-10}$  sec on  
counting rates has been observed with  $^{137}\text{Ba}$  at a distance  
of 10 cm (a distance equivalent to  $\sim 10^{-10}$  sec) and the range of  
a 0.05 sec effective counting rate has been observed after  
bombardment. Data obtained with this source plotted as  
a straight line with a half life of  $10^{-10}$  sec. After  
examination of this  $^{137}\text{Ba}$  source activity over the whole  
counting rate range the maximum range equivalent of the  
effective range obtained a half life of  $\sim 10^{-10}$  sec. This  
procedure permits the estimation of half life  
values for the determination of the  $^{137}\text{Ba}$  source and  
the results are in good agreement with the  $^{137}\text{Ba}$  source  
of decay reported by Hall. <sup>(1)</sup> The effective estimation of  
the method of least squares in the  $^{137}\text{Ba}$  source results  
in the resolution of a straight line component. (Fig. 4)  
Half life determinations were also made from counting  
rates of counting rate vs time recorded with a scaler  
of specific frequency with the  $^{137}\text{Ba}$  source. The  
method of curve resolution previously outlined was  
employed and a half life of  $10^{-10}$  sec was obtained  
resulting in half lives of 10 hours, 10 hours, and 10.7  
days.







## B. Absolute $\beta$ Activity

Since the efficiency of the  $4\pi$  counter for  $\beta$  counting is quite high (Appendix I), these data were used in the determination of absolute  $\beta$  activities. The zero time activities obtained in applying the method of least squares to half-life determination were corrected to the time of completion of bombardment. These results can be specified in terms of yield if specific values of deuteron beam current and arsenic separation efficiency are assumed.

## C. Maximum $\beta$ Energies

These values were found from absorption curves obtained by use of the end window  $\beta$  counter (Appendix III). From measurements of maximum range made at various times the energy of the most energetic  $\beta$  was determined for both the 26 hour and the 17.5 day isotopes. The method is illustrated in Fig. 5 which is applicable to the 26 hour isotope.

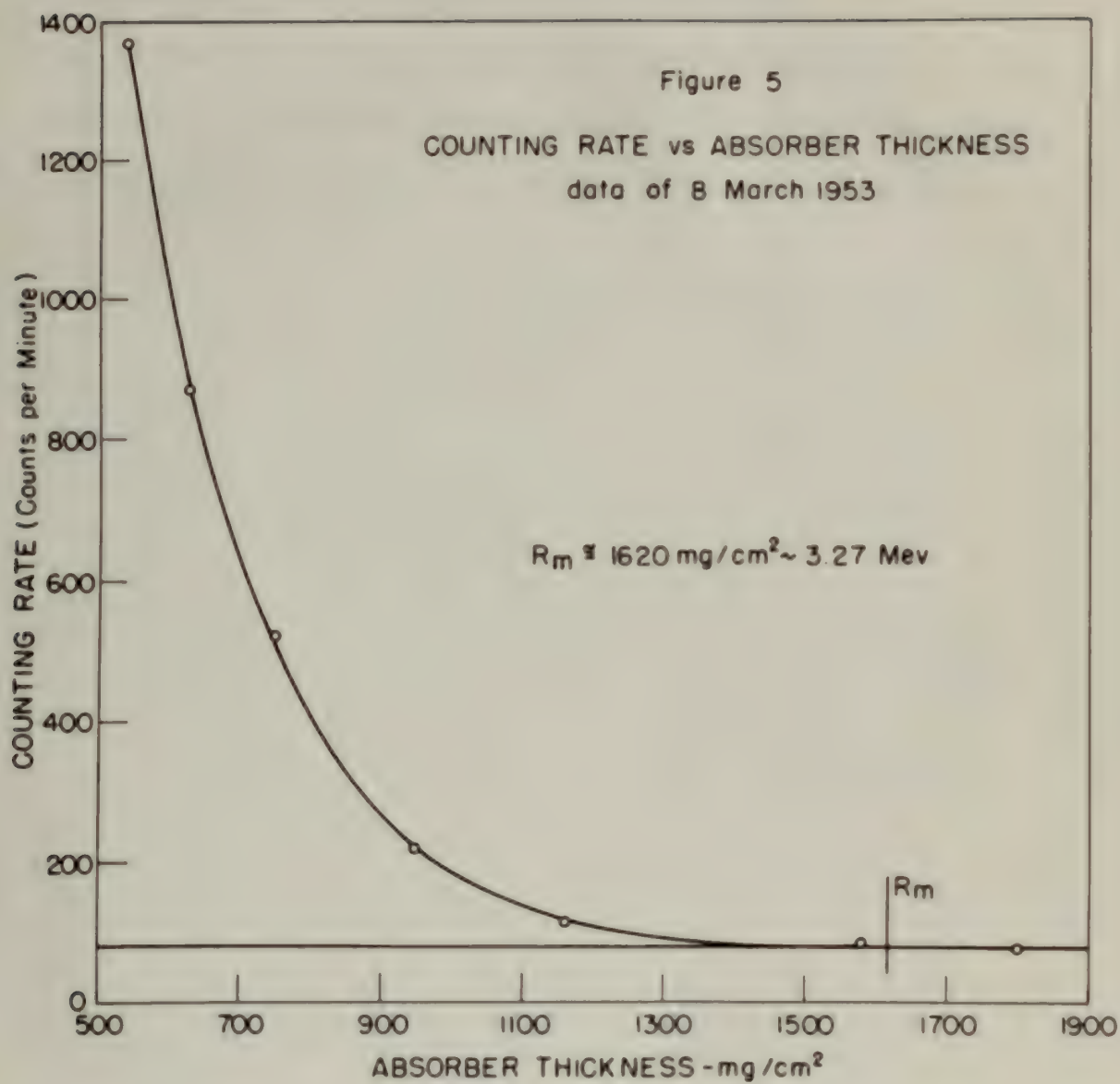
In addition, mass absorption coefficients were determined from semilog plots of counting rate vs absorber thickness taken at various times. Using these values maximum  $\beta$  energies were determined for the 17.5 day and

B. Absolute & Relative

[illegible]

C. Maximilian & Elizabeth

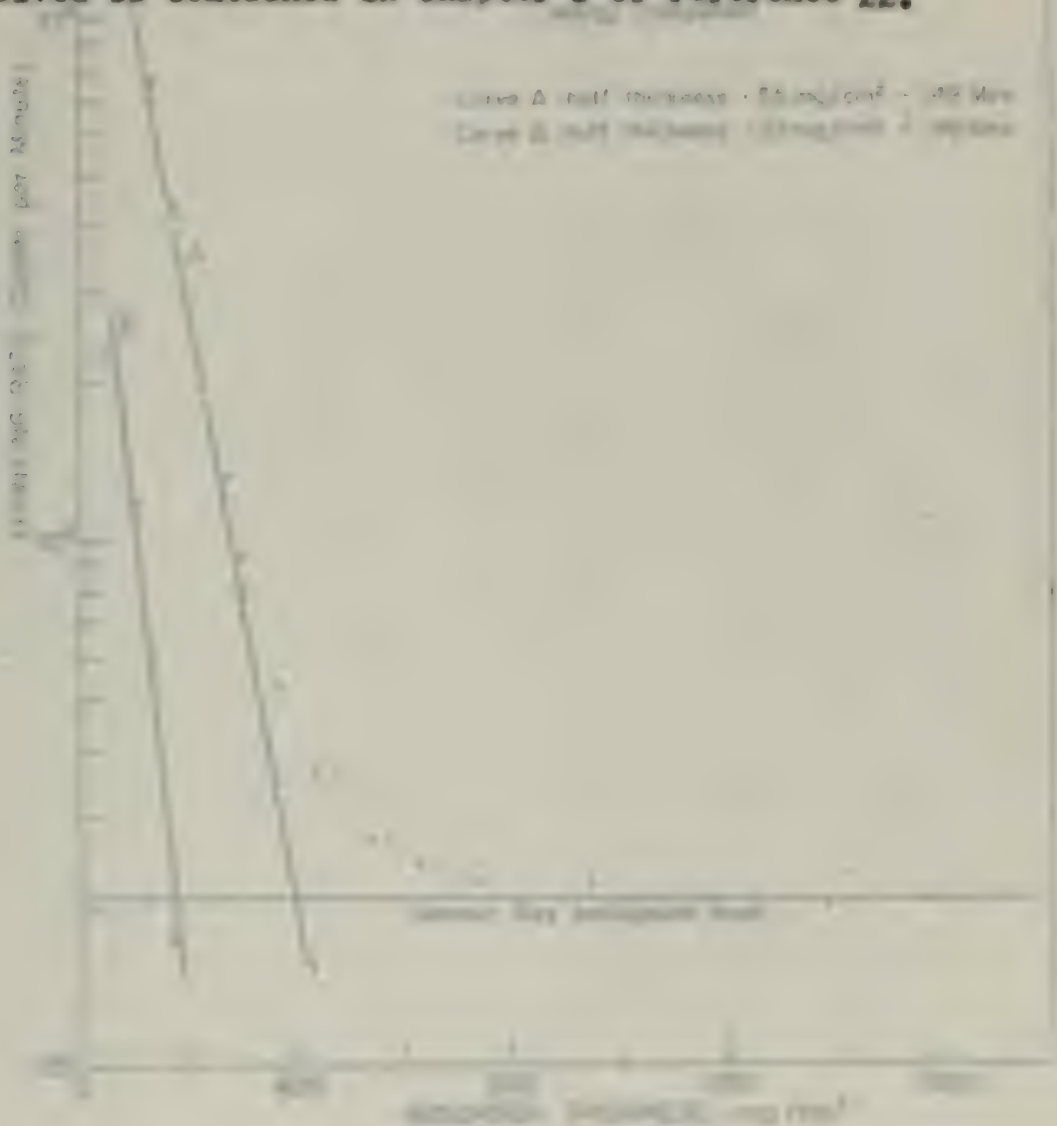
These values were found from observation to be obtained by use of the one minus 2 number formula. The measurements of minimum range made at various times the results of the most complete 2 was considered but not the 20 hour and the 17.5 day test. The reason is that tested in 17.5 is what is applicable to the 20 hour test. In addition, most chemical reactions were done at about the same place of cooling rate as observed. The reason is that the 20 hour test was done at the same place of cooling rate as observed. The reason is that the 20 hour test was done at the same place of cooling rate as observed.







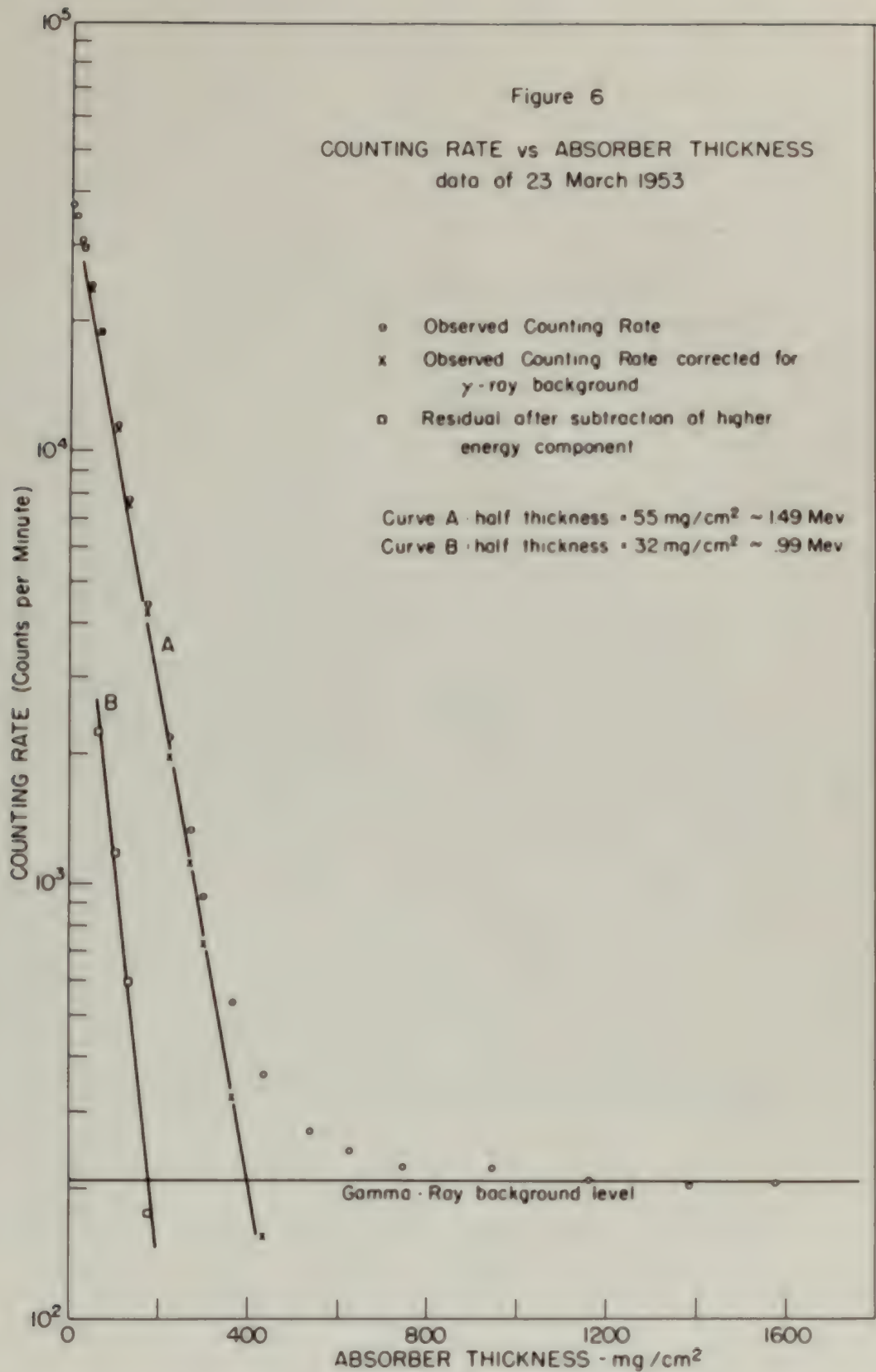
the 59 hour isotopes (Figs. 6, 7). The value obtained by this method for the 17.5 day isotope agrees with that found by the maximum range measurement stated above. The curve obtained for the 26 hour isotope (Fig. 8) was concave toward the origin and could not be treated by this method. A detailed discussion of the method and theory involved is contained in Chapter I of reference 22.



the 10 hour language (Fig. 4, Y). The value obtained  
by this method for the 10 hour language agrees with that  
found by the maximum range measurement method (Fig. 4, X). The  
curve obtained for the 10 hour language (Fig. 4, Y) was com-  
pared with the value obtained by this method for the 10  
hour language. A detailed discussion of the method and results  
involved is contained in Chapter I of reference 10.

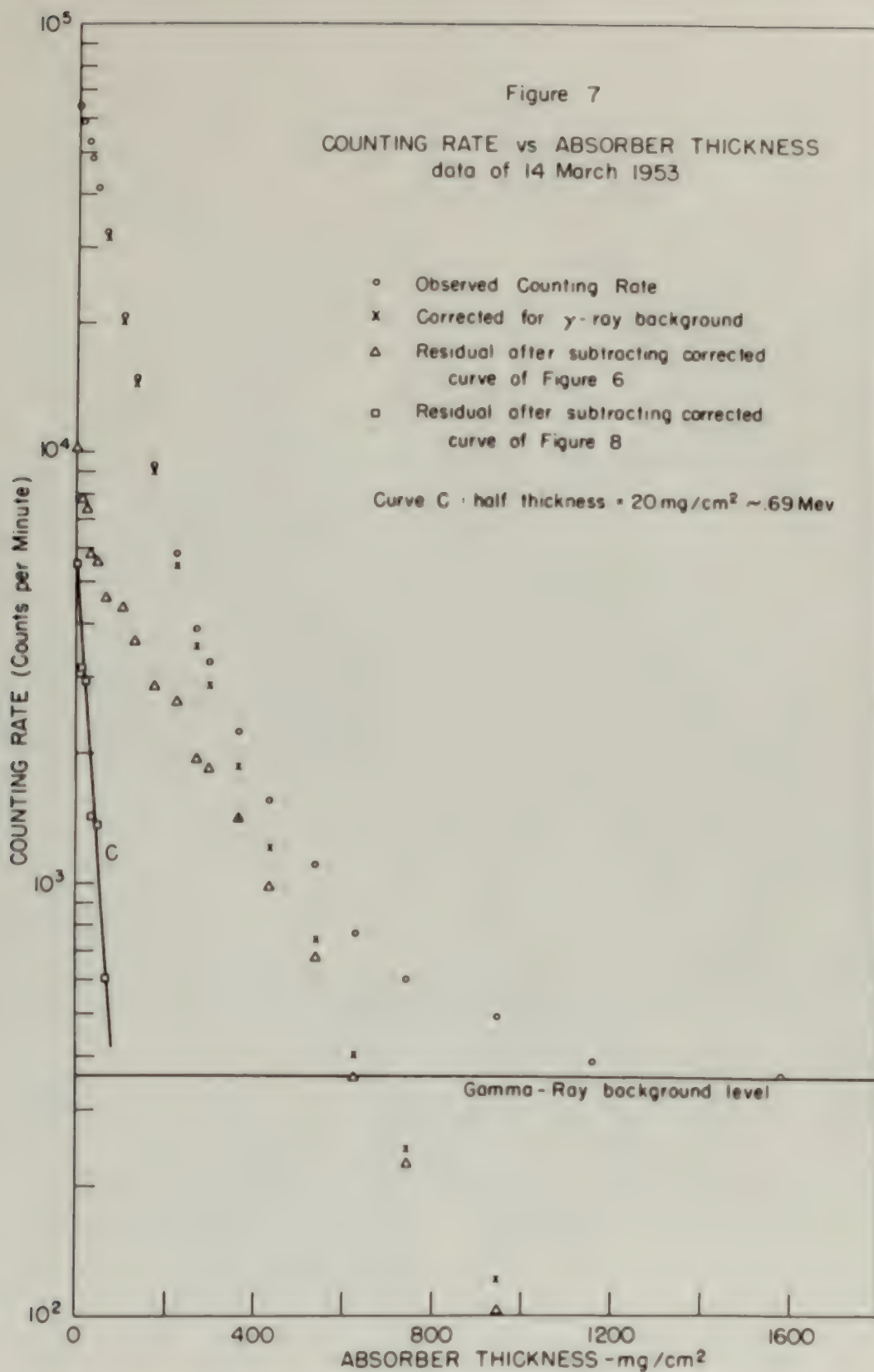
Figure 6

COUNTING RATE vs ABSORBER THICKNESS  
data of 23 March 1953

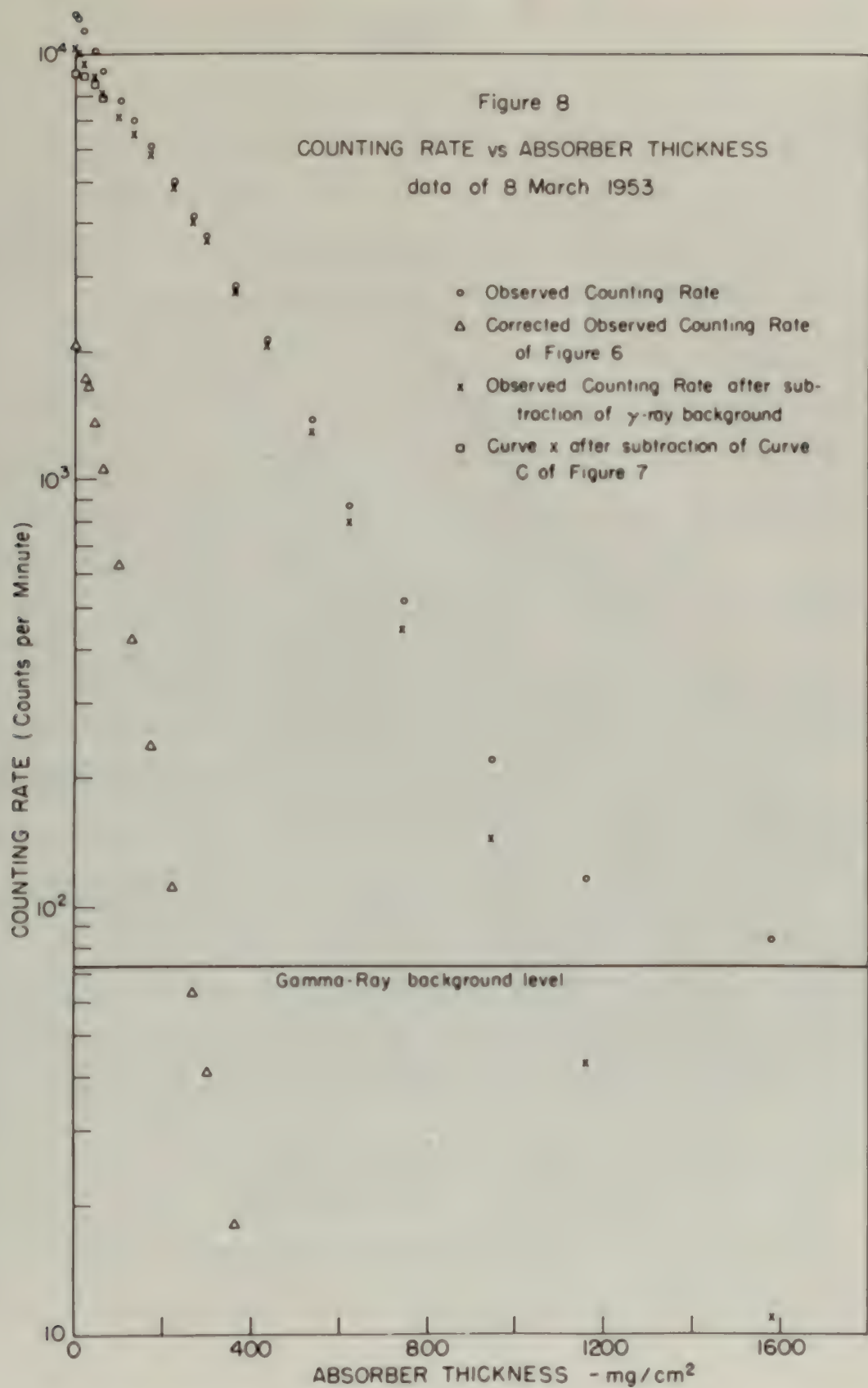
















## V. RESULTS

1. The longest-lived isotope present in the mixture was detected by only the 4 $\pi$  counter. The half life was determined to be  $86.9 \pm 9.2$  days and by the filtering method described in Section IV A, the maximum  $\beta$  energy was found to be  $0.11 \text{ Mev} > E_{\text{max}} > 0.02 \text{ Mev}$ . Since this isotope was not detected with the coincidence counter it is assumed to be a pure negatron emitter. This nuclide is believed to be As<sup>73</sup> due to the close agreement with the reported characteristics of that isotope.<sup>(11)</sup>

2. With 4 $\pi$ , coincidence, and end window counters a half life of approximately 17.5 days was resolved. Two  $\beta$  energies of this nuclide were determined by absorption measurements to be 0.99 Mev and 1.49 Mev. The close agreement of these results with those previously reported<sup>(9,11,19)</sup> seem to justify the assumption that this isotope is As<sup>74</sup>.

3. End window  $\beta$  counter measurements using an absorber thickness of  $224 \text{ mg/cm}^2$  indicated that no isotopes were present having  $\beta$  energies  $> 0.7 \text{ Mev}$  and half lives in the range  $16.7 \text{ days} > T_{1/2} > 26 \text{ hours}$ . Using lesser amounts of absorber a half life of approximately 59 hours was resolved. The only other half lives found to have this approximate value were  $70.1 \pm 2.8$  hours from 4 $\pi$  counter data and  $48.2 \pm 1.2$  hours from coincidence measurements.

## V. RESULTS

1. The longest-lived isotope known in the nucleus was detected by only the  $\alpha$  method. The half-life was determined to be  $10.5 \pm 0.5$  days and the  $\alpha$  energy emitted described in Section IV. The maximum  $\alpha$  energy was found to be  $5.11 \text{ MeV} < E_{\alpha} < 5.16 \text{ MeV}$ . Since this isotope was not detected with the calorimetric method it is assumed to be a pure negative emitter. This emitter is believed to be  $^{137}\text{Ba}$  in the chain of decay of  $^{137}\text{Cs}$ . The reported characteristics of this isotope are:

2. The  $\alpha$  energy,  $E_{\alpha}$ , and the  $\alpha$  energy spectrum of half-life of approximately 17.5 days are recorded. The  $\alpha$  energy of this emitter was determined by comparison measurements to be  $5.16 \text{ MeV}$  and  $1.44 \text{ MeV}$ . The  $\alpha$  energy

agreement of these results with those previously reported (11,12) seem to justify the assignment that this isotope is  $^{137}\text{Ba}$ . 3. The  $\alpha$  energy spectrum measurements using an absorber

thickness of  $0.04 \text{ cm}^2$  indicated that an isotope with prominent  $\alpha$  energy  $> 5.1 \text{ MeV}$  and half-life in the range  $10.5 \text{ days} < T_{1/2} < 10 \text{ years}$ . Using these criteria of absorber a half-life of approximately 10 years was resolved. The only other half-life known to have this approximate value was  $^{137}\text{Ba}$   $\pm 1.5$  years. Thus an emitter with  $10.5 \pm 1.5$  years half-life was assigned.



The latter value combined with the energy limitation previously specified justifies identification of this isotope as  $\text{As}^{71}$ . (10,11,12) The longer half life values obtained from  $4\pi$  and end window counter measurements indicate that there is also present a negatron emitter having a  $T_{1/2}$  longer than 70 hours with energy  $< 0.7$  Mev. The 70 hour half life determined from  $4\pi$  counter measurements is believed due to a mixture of  $\text{As}^{71}$  and  $\text{As}^{77}$  assuming that the single reported value for the half life of the latter (20) is in error. This apparent discrepancy is worthy of future study.

4. From data of the  $4\pi$  and end window  $\beta$  counters a component of half life  $25.8 \pm 0.2$  hours with a maximum  $\beta$  energy of 3.25 Mev was determined. A  $\gamma$ -ray energy of 0.85 Mev with half life approximately 29 hours was found from measurements made with the  $\gamma$ -ray scintillation spectrometer. These results confirm previously reported values (9,11,13) and identify this isotope as  $\text{As}^{72}$ . This half life determined from coincidence measurements was  $21.7 \pm 0.2$  hours.

5. There was no indication of the presence of the 52 minute  $\text{As}^{70}$  isotope (9) in the mixture. In addition, since no  $\gamma$ -ray energies  $> 0.85$  Mev were resolved it was

The latter value compares with the mean likelihood  
previously reported for the likelihood of this  
sample as  $27.1 \pm 1.0$ . The larger and the value  
obtained from the two other common measurements  
indicate that there is also present a negative effect  
which is larger than the mean value  $< 0.7$   
has. The  $\chi^2$  test for the likelihood of the  
measurements is believed to be a measure of the  
likelihood that the single reported value for the  
likelihood of the latter  $27.1 \pm 1.0$  is in error. This is the  
measure of the likelihood of the latter value.

1. From date of the 1st of January 1900 to the 31st of December 1900, the total number of cases of smallpox in the United States was 1,000. This was a decrease of 100 cases from the year 1899, when the total number of cases was 1,100. The number of cases in 1900 was 1,000, which was a decrease of 100 cases from the year 1899, when the total number of cases was 1,100. The number of cases in 1900 was 1,000, which was a decrease of 100 cases from the year 1899, when the total number of cases was 1,100.

1. There was no indication of the presence of the



apparent that the 27.6 hour  $\text{As}^{76}$  isotope having two reported  $\gamma$  energies  $> 1 \text{ Mev}$  (14, 18) was not present.

6. Tabular summary of characteristics of the mixture of radionuclides determined by this investigation.

Isotopes	Method of decay	Energy (MeV)	T <sub>1/2</sub>	Thick target yield* (uc/amp-hr)
As <sup>71</sup>	β <sup>+</sup>	0.66	48.2 ± 1.2 hrs.	7.6
As <sup>72</sup>	β <sup>+</sup>	3.25	25.8 ± 0.2 hrs.	64.9
	γ	0.85		
As <sup>73</sup>	β <sup>-</sup>	0.11 > E <sub>max</sub> > 0.02	88.9 ± 9.2 days	1.1
As <sup>74</sup>	β <sup>+</sup>	0.99, 1.49	17.82 ± 0.13 days	5.2
	β <sup>-</sup>			
As <sup>76</sup>	Not present in the mixture			
As <sup>77</sup>	β <sup>-</sup>	< 0.7	> 70 hours	5 < yield < 15**

\* The thick target yield values specified apply if the deuteron beam current was exactly 36  $\mu\text{amps}$  and if the arsenic separation efficiency was 100 percent. Yield values quoted are based on  $\beta$  counting only and do not include orbital electron capture.

\*\* Based on ratios of total  $\beta$  to  $\beta^+$  counting rates.

At present the 77.9 mm  $^{87}\text{Rb}$  line is not observed in the spectrum of the sample, but it is observed in the spectrum of the standard.

3. The intensity of the 77.9 mm  $^{87}\text{Rb}$  line is not observed in the spectrum of the sample, but it is observed in the spectrum of the standard.

Sample	Standard	Intensity	Frequency	Wavelength
1.1	1.1	1.1	1.1	1.1
1.1	1.1	1.1	1.1	1.1
1.1	1.1	1.1	1.1	1.1
1.1	1.1	1.1	1.1	1.1

Not observed in the spectrum

The 77.9 mm  $^{87}\text{Rb}$  line is not observed in the spectrum of the sample, but it is observed in the spectrum of the standard. The intensity of the 77.9 mm  $^{87}\text{Rb}$  line is not observed in the spectrum of the sample, but it is observed in the spectrum of the standard.

on the basis of the 77.9 mm  $^{87}\text{Rb}$  line.

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# Appendix I

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SECTION 1



# APPENDIX I

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## Lecture IV To: Judd

[illegible]



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## A. Description of the Counter

The 4r 5011A type counter was designed as a portable laboratory instrument to be used for the efficient determination of  $\beta$  activities. A photograph of the instrument is shown in Fig. 1. This illustrates the important features of construction and source mounting. Detailed specifications are given in Figs. 2 and 3.

The sensitive volume of the counter is geometrically similar to that of a parallel plate counter. The counter was designed and operated as a flow counter using a butane gas rather than as a fill counter due to the fact that the former is more stable and less subject to contamination. Since the counter must be opened each time a source is changed, use as a flow counter which eliminates the necessity for a window and greatly simplifies the operating procedure as compared with that of a fill-type counter. The O-



## APPENDIX I

### THE 4 $\pi$ COUNTER

---

#### A. Description of the Counter

The 4 $\pi$  solid angle counter was designed as a convenient laboratory instrument to be used for the absolute standardization of  $\beta$  emitters. A photographic view of the disassembled counter, Fig. 1, illustrates the important features of construction and source mounting. Detailed specifications are given in Figs. 2 and 3.

The sensitive volume of the counter is geometrically similar to that of Caswell<sup>(1)</sup> and of Borkowski<sup>(2)</sup>. The counter was designed and operated as a flow counter using n butane gas rather than as a fill counter due to the fact that the former is more stable with far better reproducibility<sup>(2)</sup>. Since the counter must be opened each time a source is changed, use as a flow counter which eliminates the necessity for a vacuum seal greatly simplifies the operating procedure as compared with that of a fill-type counter. The 0-

given in Part I and II.

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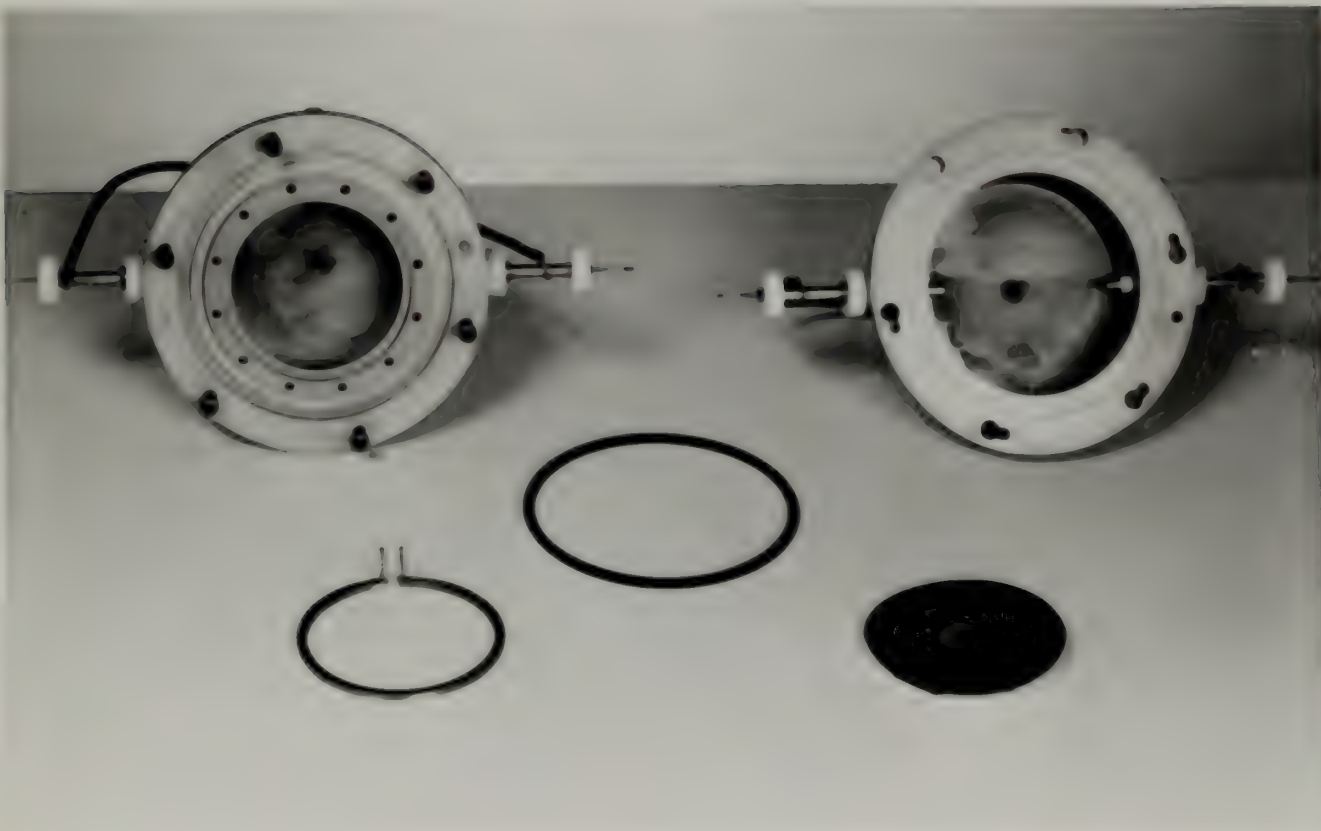




**Fig. 1. Photograph of disassembled counter.**

The upper view shows the source ring in place with the top half of the counter removed. The active source is the dark circular area in the center of the thin film which appears as a light area in the center of the source ring.

The bottom view shows the completely disassembled counter. The retaining ring for holding the source ring in place is shown with the removable handling pins in place.











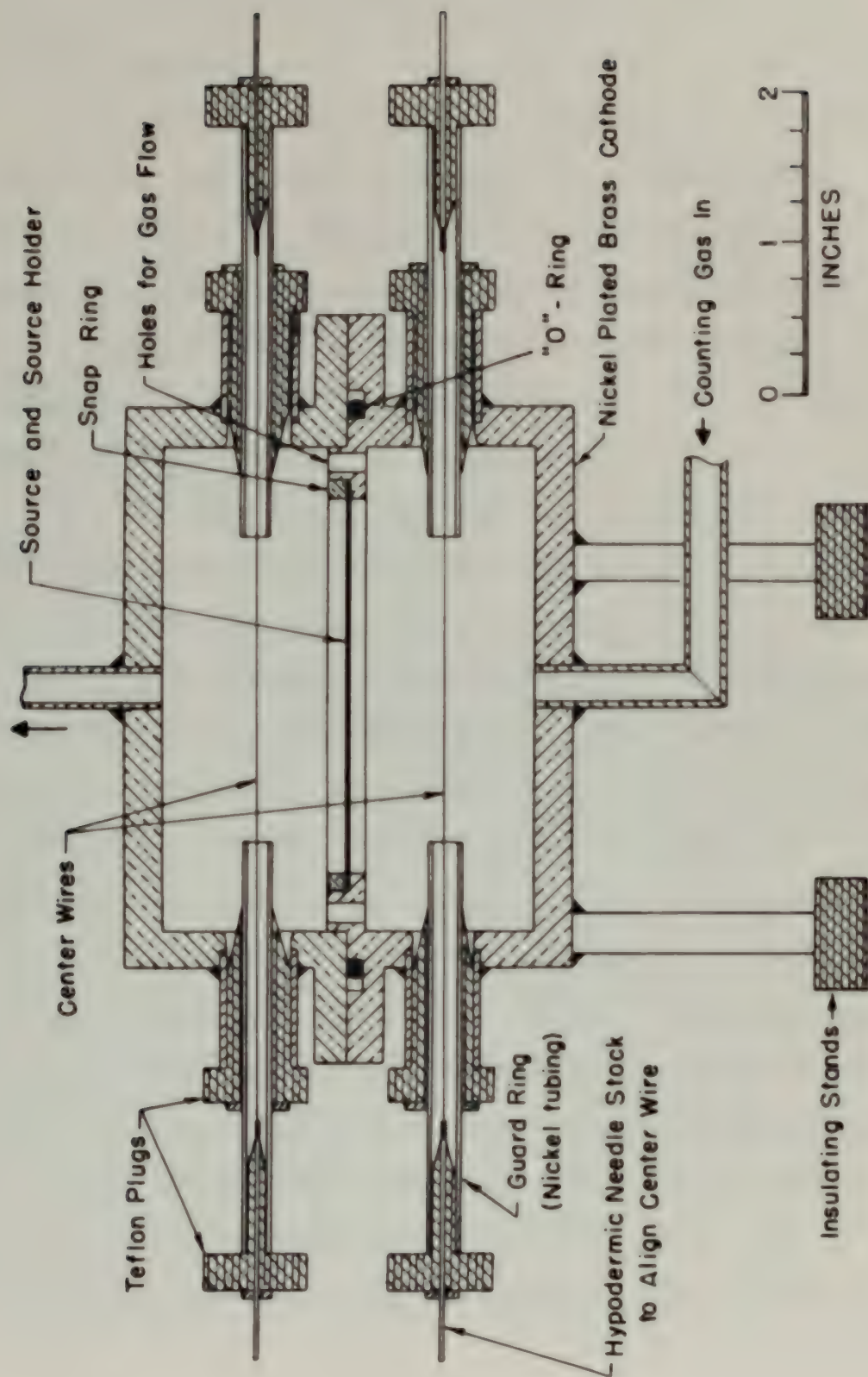


Figure 3  
CROSS SECTION OF  $4\pi$  PROPORTIONAL FLOW COUNTER





ring seal is used to reduce leakage of flow gas to an absolute minimum.

Squeeze-fitted Teflon plugs are used instead of Kovar glass for counter case-to-guard ring and guard ring-to-center wire insulation, with all insulator surface leakage paths designed for approximately 5000 volts. This feature is for convenience in assembly, cleaning of the sensitive volume, and to minimize the possibility of breakage in handling.

The 1/4 inch thick counter case is machined from 5 inch brass stock, all sleeve entries to the case being silver-soldered and the entire assembly nickel-plated to facilitate cleaning. Center wires of 1 mil tungsten are aligned by 20 gauge hypodermic needle stock to which they are soldered at the extremities. Center wires are guard-ringed with the guard rings at the same high positive potential as the center wires. The tripod legs supporting the counter fit into insulating stands made of drilled polystyrene rod stock. A grounded brass shielding box contains the entire counter assembly and minimizes externally-caused electromagnetic interference. Electrical connections within the box are made with rubber-covered wire insulated for 5000 volts. All electronic connections to the shielding box are made

ring seal is used to reduce leakage of flow gas to an  
absolute minimum.

Spun-on-Cliffed Teflon rings are used instead of  
heavy rings for several cases--to prevent ring and gasket  
ring-to-sealer wire insulation, with all insulation  
surface leakage being designed for approximately 5000  
volts. This feature is for convenience in assembly,  
eliminating of the sensitive volume, and to minimize the  
possibility of discharge in handling.

The life time which occurs here is measured from 5  
last three weeks, all other entries in the case being  
silver-soldered and the entire assembly nickel-plated  
to facilitate cleaning. Center wires of 1 mil diameter  
are aligned by 10 mils hypodermic needles when in which  
they are soldered at the extremities. Center wires are  
fracture-tipped with the quartz rings at the same high  
positive potential as the center wires. The tripod  
legs supporting the counter are also supporting stands  
made of drilled polystyrene rod stock. A grounded brass  
shielding box contains the entire counter assembly and  
includes externally-vented electrostatic interference.  
Electrical connections within the box are made with  
rubber-covered wire insulated for 5000 volts. All  
electronic connections to the shielding box are made



by coaxial cable and associated fittings. A U-tube oil-filled bubbler external to the shielding box maintains gas pressure within the counter slightly above atmospheric and avoids changes in gas concentration.

Three mil shim steel stock\* provides a sturdy source mounting ring. The steel is first cut into 3 inch squares and a 5/8 inch hole is punched in the center of these squares. The 2 3/4 inch outer diameter is then obtained by use of a jig and ordinary paper shears. The prepared source ring is held in place in the counter by use of a split brass ring (similar to a piston ring).

To retain some of the pulse limiting properties of the conventional Geiger counter while eliminating many of its objectionable features, the 4w counter is operated in the region of limited proportionality. (4, 5) The counter is operated at a well regulated 4300 volts with the cathode 2500 volts below ground and center wires and guard rings 1500 volts above ground to minimize corona and "spurty" noise effects. This operating point is approximately 500 volts above the beginning of a counting rate plateau which is better than 0.5 percent per 100 volts. The center wire output is fed

---

\* Obtainable from Ward Steel Co., Arlington, Mass.

by special order and authorized personnel, a 1000  
 additional personnel assigned to the building for maintenance  
 and repairs. The building is under strict security and  
 access and egress is controlled in the building.

Three all steel plates riveted a heavy  
square mounting plate. The steel is 1/2 inch thick  
and square and a 1/2 inch hole is centered in the  
center of each plate. The 1/2 inch hole is riveted  
in steel and is a 1/2 inch hole in the  
center. The square plate is 1/2 inch thick in  
the center by use of a 1/2 inch hole (center to a  
center line).

To verify some of the above limited hypotheses  
 of the experimental design various other experiments  
 were of an experimental nature. The first was to  
 operate in the region of liquid crystalline  
 The system is composed of a well regulated flow  
 with the volume flow rate being constant and  
 after the flow rate had been determined in each  
 case the "critical" flow rate was determined. This was  
 done by approximately 500 units above the beginning  
 of a constant rate phase which is better than 10  
 percent per 100 units. The center line value is the



to a Model 100 amplifier through a cathode follower preamplifier (Atomic Instrument Co. Model 204-B) with the amplifier output driving an M.I.T. Model 400-R decade scaler. The counter with associated electronic equipment connected for normal operation is illustrated in Fig. 4.

#### B. Applicability to Absolute $\beta$ Counting

If a counter is built which collects particles emitted from a source in all directions, it has many advantages for measurement of absolute activity. First, since all particles emitted from the source are counted, a direct measurement of the  $\beta$  disintegration rate is made without the need for precise knowledge of the solid angle with its accompanying scattering problems. Also, since the "efficiency for  $\beta$  particles" is now 100 percent, much smaller and thinner sources may be prepared thus reducing the self-absorption considerations.<sup>(8)</sup>

In the  $4\pi$  counter, any  $\beta$  particle which produces an ion pair outside the source and source mounting will be counted unless this ion pair is formed in a region of low enough intensity that recombination occurs prior to

to a total 100 supplies through a volume of 100  
supplies (100 supplies) (100 supplies) (100 supplies)  
the supplies subject to the 100 supplies (100 supplies)  
100 supplies. The number of supplies is 100 supplies  
100 supplies. The number of supplies is 100 supplies

[illegible]

It is a common knowledge that the Government of the United States has been for many years engaged in a policy of "containment" against the Soviet Union. This policy has been based on the assumption that the Soviet Union is an expansionist power and that it is necessary to prevent it from becoming a world power. The Government has used a variety of means to achieve this end, including military, economic, and diplomatic measures. The result has been a long and costly struggle, which has not yet reached its conclusion.



**Fig. 4. Photograph of counter with electronic equipment connected for normal operation.**

The insulating polystyrene mounts are visible within the brass shielding box and the oil-filled bubbler is shown on the outside lower left corner.







initiation of the Townsend avalanche. Consideration of the geometry of and the fields existing in the sensitive volume indicates a very small probability for counting losses due to this effect. (1)

Any ionization produced by internal conversion electrons, branched spectra,  $\gamma$ -ray spectra, and electrons produced in the counter walls or in the gas will merely add to the total ionization per disintegration and will therefore be counted as a single pulse. This is also true of annihilation radiations and this fact makes the  $4\pi$  solid angle method valid for the assay of positron emitters.

Deviations from 100 percent absolute efficiency will be due only to (a) absorption in the source and source mounting film, (b) areas of low field intensity mentioned above, and (c) resolving time losses.

### C. Important Aspects of Source Preparation

The preparation of a thin source is the most difficult problem involved in the practical use of the  $4\pi$  counter. It is essential that the source be quite thin and uniform for any isotope emitting soft  $\beta$  particles. The

initiation of the Townsend mechanism. Consideration of  
the geometry of and the fields existing in the resonant  
volume indicated a very small probability for coupling  
losses due to this effect. (1)

Any limitation presented by lateral conversion  
electrons, internal space, wave spectra, and absorption  
presented in the resonant volume as in the gas will merely  
add to the total limitation for elimination and will  
therefore be counted as a single value. This is also  
true of scattering phenomena and this fact means the  
an solid angle within which the wave of position  
exists.

Deviations from the Townsend scheme of operation  
will be the only (a) absorption in the resonant and  
waves existing (b) areas of low field intensity  
existing above, and (c) resulting from losses.

## 2. Important aspects of wave propagation

The propagation of a thin wave in the most difficult  
problem involved in the practical use of the resonant.  
It is essential that the waves be given time and space  
from for any change existing with a position. The



chemistry involved in preparing uniform thin sources varies with the element involved. When a sample is simply allowed to dry, the active material has a tendency to crystallize out as one or more large particles or to dry in a thick ring of small crystals around the edge of the drop. Use of an infrared lamp speeds evaporation and reduces the tendency to "cluster" in every case attempted. It has been empirically determined that counting losses due to self-absorption can be neglected if the maximum solid content of the source is  $\leq 5 \mu\text{gm}$  for  $\beta$  energies  $\geq 0.6 \text{ Mev}$ , but for  $\beta$  energies  $\leq 0.4 \text{ Mev}$  solid content of the source should not exceed  $0.1 \mu\text{gm}$ . These approximate values are based on a total pipetted source volume of  $0.085 \text{ ml}$ . Within the specified limits, self-absorption losses are negligible compared to losses in the conductive layer on the source mounting film. Self-absorption can never be entirely eliminated by continued reduction of total solids since there is a finite particle size which the material must assume upon precipitation. It has been shown that below a certain very small concentration, a decrease in solids does not increase the observed counting rate. Also, a slight increase in solids above this value does not decrease the observed counting rate of a source.<sup>(3)</sup>

essentially identical in composition with the samples  
 taken from the same interval. When a sample is  
 already allowed to dry, the degree of crystallinity is  
 determined by crystallization and as such no more large  
 particles or in dry in a solid state of small crystals  
 around the edge of the film. One of the largest large  
 crystals crystallized and reduced the tendency to "fingerprint"  
 in every case attempted. It was found experimentally  
 determined that crystallization does in self-crystallization  
 can be neglected if the maximum width of the  
 sample is  $\leq 4$  mm for 5 crystals  $\leq 4.5$  mm, but the  
 4 crystals  $\leq 3.4$  mm width of the sample should  
 not exceed 0.1 mm. These experimental values are listed  
 on a table of the experimental values of 0.1 mm. Within  
 the specified limits, self-crystallization does not affect  
 the composition of the sample in the crystalline layer as the  
 sample mounting film. Self-crystallization can never be  
 directly eliminated by crystallization of the film  
 which since there is a limit to the size of the  
 crystalline layer, it has been  
 shown that below a certain very small crystalline  
 thickness in which case the increase in crystallinity is  
 small. Also, a slight increase in crystallinity above the value  
 does not increase the observed mounting rate of a polymer.



#### D. Preparation of Source Mounting Film

A solution made by dissolving 5 grams of stick parlodion\* in 85 ml of amyl acetate was found to produce the most durable very thin uniform films. A period of about two weeks, with frequent agitation, is required for the formation of the solution.

Thin films are made by dropping an appropriate amount of the above solution on a clean surface of distilled water. The water used should first be boiled to eliminate dissolved gases and an indicator such as phenolphthalein should be added in order to check pH. Water which is even slightly acidic seems to decrease the physical strength and life of the film produced. A room should be chosen which is as dust- and draft-free as possible and a strong light is essential for inspecting the films and the water surface.

The simplest and most expeditious method is as follows:

1. Fill an 8-10 inch diameter culture dish to overflowing with the water prepared as indicated above.
2. Express two drops of parlodion solution on the clean water surface and observe the color display under a strong white light as the film spreads.

\* Obtainable from Central Scientific Co., N. Y.

10. The Commission is of the opinion that the Commission should be authorized to investigate the activities of the Commission.

[illegible]

As of 2008, approximately 100,000 people are still in the U.S.

1. With the 7-10 inch diameter valves this is  
overlooking with the water pressure as indicated above.
2. Express two days of production solution at  
the clean water surface and observe the same during  
water & steam well light as per this process.
- A detailed flow chart follows page 11.



3. When maximum color display is evident near the edges of the film, drop the prepared source ring horizontally from a height of about 1/2 inch onto the center of the floating parlodion film.

4. Holding one edge of the floating source ring and attached film, trim away the excess film with a very sharp knife. The ring is then slid from the surface of the water at a small angle to avoid surface tension film breakage and may be placed vertically in a drying rack.

5. Film thickness may be determined by observation of reflected color under white light and comparison with available curves which read directly in  $\mu\text{g}/\text{cm}^2$  (Fig. 5). For more accurate determination, the  $\alpha$  thickness gauge may be used. This consists of a collimated source of polonium fastened to a movable micrometer jaw which is mounted vertically above a thin window Geiger counter. A zero reading of the end of the  $\alpha$  particle range is made, after which the film is placed over the counter window and the measurements repeated. The distance between the two curves so obtained gives the absorption of the film in air-cm, which can be translated directly into  $\mu\text{g}/\text{cm}^2$ . The gauge is capable of measuring thicknesses as small as 1  $\mu\text{g}/\text{cm}^2$  with less than 10 percent error.

1. The Commission will discuss the results of the study at the end of the year, and will also discuss the results of the study at the end of the year.

4. The following was said by the witness in his deposition on 11/11/1964:

It is difficult to say whether the film is a success or a failure. The story is a good one, and the acting is good. The film is well made, and it is a pleasure to watch. The story is a good one, and the acting is good. The film is well made, and it is a pleasure to watch.

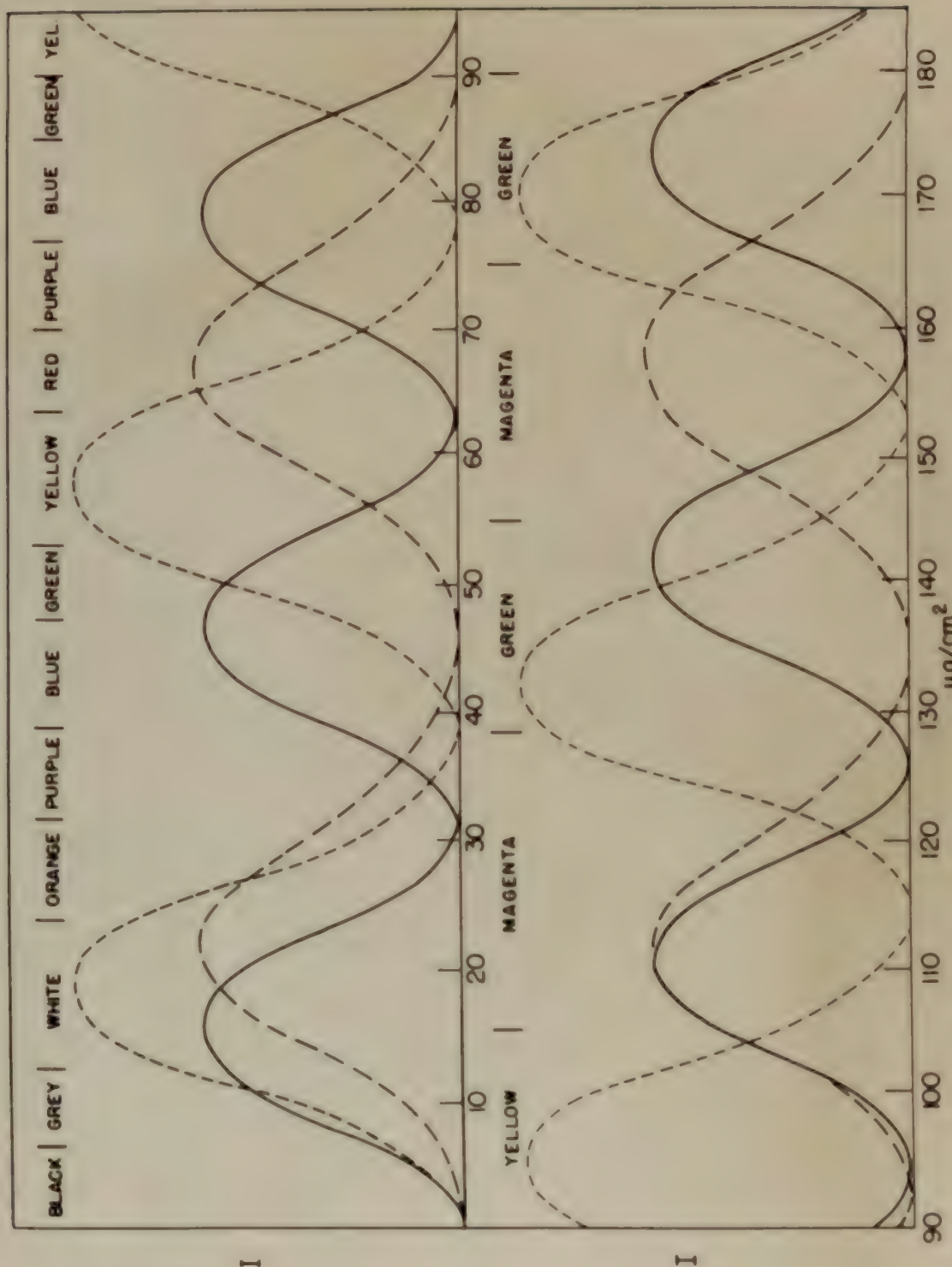


Figure 5 INTENSITY OF REFLECTED LIGHT vs FILM THICKNESS





## E. Conducting Layer for Source Mounting Film

For absolute measurements, it is essential that the collecting field within the counter not be distorted by the dielectric-covered hole in the source ring. A thin conducting metallic layer which covers the entire source support may be evaporated from a heated tungsten filament, the evaporation being performed in a vacuum of approximately 1 micron. To insure electrical contact with the counter case, the layer should be deposited on the side of the source ring opposite that to which the parlodion film adheres. The apparatus used for metallic evaporation is illustrated in Fig. 6 where the method of supporting the source ring described below is clearly visible. Since the greatest danger of film breakage occurs in the metallic evaporation process, this operation should be performed prior to pipetting the active source material.

For source solutions which do not contain hydrochloric acid, aluminum produces a suitable conducting layer and the following procedure is recommended.

1. Place the prepared source ring horizontally atop a length of 50 mm diameter glass or pyrex tubing which encloses the prepared tungsten filament. The

[illegible]

Later and the following paragraph is very important.

1. There are several reasons why the Commission should not be established. First, it is not clear that the Commission would be able to do anything that the existing agencies are not already doing. Second, it is not clear that the Commission would be able to do anything that the existing agencies are not already doing. Third, it is not clear that the Commission would be able to do anything that the existing agencies are not already doing.

THE UNIVERSITY OF CHICAGO PRESS

CHICAGO, ILL.

1914

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PUBLISHED BY THE UNIVERSITY OF CHICAGO PRESS  
CHICAGO, ILL.  
1914

**Fig. 8. Photograph of apparatus used in metallic evaporation.**

The source ring lying on top of the cylindrical glass tubing under the bell jar is in proper position for aluminum evaporation. Tubing which carries cooling water for the filament electrodes is visible to the left of the bell jar.







source ring should be approximately 7 cm above the filament for a vacuum of 1  $\mu$ .

B. When a vacuum of 1  $\mu$  is reached, slowly increase filament current until the aluminum begins to evaporate from the filament. Observe the climb of deposited aluminum on the glass tube and when it reaches the top of the tube, shut off filament current. This procedure results in uniform conducting layers of from approximately 10 to 15  $\mu\text{g}/\text{cm}^2$  in thickness.

The hydrochloric acid in many source solutions will interact with the aluminum surface of the source mounting and frequently causes a decrease in counting efficiency. In such cases a thin layer (15-20  $\mu\text{g}/\text{cm}^2$ ) of gold produces a suitable conducting surface. A standard microscope slide placed at the same vertical distance above the evaporating filament as the source mounting film and coated simultaneously with the source film provides a measurement of the thickness of gold. A resistance across the length of the slide measuring between 50 and 200 megohms indicates a thickness of gold between 15 and 20  $\mu\text{g}/\text{cm}^2$ . (3)

For the measurement of isotopes having  $\beta$  energies greater than 1 Mev, aluminum foil of 0.1 mil thickness\*

---

\* Obtainable from Frank H. Caffin and Son, 22 Elm St., Hyde Park, Mass.

current that should be approximately 7 to 10 volts per  
 filament for a vacuum of 1  $\mu$ .  
 5. When a vacuum of 1  $\mu$  is reached, slowly  
 increase filament current until the aluminum begins  
 to evaporate from the filament. Observe the color  
 of deposited aluminum on the glass tube and when it  
 reaches the top of the tube, turn off filament current.  
 This procedure results in uniform evaporating layers of  
 from approximately 10 to 15  $\mu\text{g}/\text{cm}^2$  in thickness.  
 The pyrochordite will be very porous and  
 will interact with the aluminum surface of the source  
 mounting and frequently causes a decrease in evaporation  
 efficiency. In each case a thin layer (10-15  $\mu\text{g}/\text{cm}^2$ )  
 of gold produces a reliable conducting surface. A  
 standard microscope slide placed at the same vertical  
 distance above the evaporating filament as the source  
 mounting film and coated simultaneously with the source  
 film provides a measurement of the thickness of gold.  
 A resistance across the length of the slide measuring  
 between 50 and 100 ohms indicates a thickness of

$$\text{Gold between } 10 \text{ and } 15 \mu\text{g}/\text{cm}^2. (1)$$

For the measurement of thickness having a sensitivity  
 greater than 1 day, aluminum will be 0.1  $\mu\text{g}/\text{cm}^2$

---

\* Depositable from Lewis G. Collins and Son, St. Louis, Mo.



may be used instead of the evaporated metallic layer with no detectable counting loss. A fine mist of distilled water is deposited on the prepared source ring by use of an ordinary bulb type atomizer. The 0.1 mil foil is then laid over the moistened source ring, carefully brushed flat with a fine camel's hair brush, and the excess trimmed off with scissors. If the above is carefully performed the foil is then inseparable from the source ring and parlodion film.

No conducting layer need be applied to the source mounting if a high degree of accuracy is not required. Elimination of the metallic layer results in counting losses of from approximately 1 percent to 3 percent depending on the maximum  $\beta$  energy of the isotope used. For example, the observed counting rate from several non-conducting  $P^{32}$  sources increased by  $2 \pm 0.5$  percent with the addition of either foil or evaporated aluminum conducting coatings.

## F. Preparation and Precipitation of Source Material

### 1. Isotopes emitting $\beta$ particles of $> 0.6$ Mev.

The best method found so far consists of adding

may be used instead of the suspended cable layer  
 with an adjustable bearing frame. A line also of  
 divided order is deposited on the suspended cable  
 and is not of an ordinary type structure. The  
 2.1 all fall in line with the suspended cable  
 they are all in line with a line cable.  
 half hour, and the cable is not with a line.  
 It is also in a specially designed line in line  
 between the two cable and the cable line.  
 The suspended cable may be applied in the cable  
 between it a line cable of suspension is not required.  
 Division of the cable layer cable in a line  
 layer of two approximately 1 percent to 1 percent  
 depending on the nature of the cable used.  
 Two examples, the observed bearing rate from several  
 non-suspended 1.5 percent interval of 1.5 to 1.5 percent  
 with the addition of either fall or suspended aluminum  
 technical details.  
 1. The cable is not of an ordinary type structure.  
 2. The cable is not of an ordinary type structure.  
 3. The cable is not of an ordinary type structure.  
 4. The cable is not of an ordinary type structure.  
 5. The cable is not of an ordinary type structure.  
 6. The cable is not of an ordinary type structure.  
 7. The cable is not of an ordinary type structure.  
 8. The cable is not of an ordinary type structure.  
 9. The cable is not of an ordinary type structure.  
 10. The cable is not of an ordinary type structure.



a small amount of Bentonite, a colloidal mud, to the pipetted drops of source solution. The source ions are adsorbed on the Bentonite which dries in a fairly uniform layer of fine particles. Microscopic observation of sources prepared in this manner yields a typical size of 1 micron for the largest particles, i.e.,  $0.1 \text{ mg/cm}^2$  for material of density 1.<sup>(1)</sup> The layer is much more uniform if instead of simply allowing the source to dry, an infrared lamp is used to decrease evaporation time.

Using the highest specific activity source material available to minimize source solid content, a solution of from 1 to 1.5  $\mu\text{C/ml}$  is prepared. This yields approximate counting rates from  $55 \times 10^3$  to  $82.5 \times 10^3$  dpm per 25 $\lambda$  of active material. Since the resolving time of the counter is approximately 20  $\mu\text{sec}$ , this range of activities limits resolving time losses to  $\leq 2$  percent.

In solutions of materials of high specific activity, considerable losses may be caused by adsorption of the active constituents on the walls of containing vessels and pipettes used in measurement.<sup>(2)</sup> This effect results in a decrease of activity in solution, especially

[illegible]

Using the highest resolution available, a resolution of 0.1 mm was used. The results of the analysis are shown in Table I. The results show that the average particle size of the polymer is 0.1 mm. This is in good agreement with the results of the other analyses.

2000

in addition to material of this sensitive nature, considerable losses may be caused by absorption of the active constituents on the walls of containing vessels and pipes used in measurement. This effect



for carrier-free materials. This loss of activity may be reduced by the addition of inactive isotopes of the same chemical form as carriers prior to preparation of the source solution. For example, a small quantity of  $KH_2PO_4$  is used with solutions of carrier-free  $P^{32}$  and  $KI$  is used with carrier-free  $I^{131}$ . The mass of carrier which may be added is determined by the permissible solid content of the solution but a desirable ratio to make adsorption negligible is approximately  $10^6$  inactive atoms per active atom.

The pH of the active solution is maintained so as to keep the active atoms in solution. For some isotopes the solution should be acidic while others require a basic solution. A general rule which has few exceptions is to prepare an acidic solution if the active atom is in the cation and a basic solution if it is in the anion. (8) In all solutions, any substance added to adjust the pH must be soluble when combined with the active material in order to prevent precipitation.

The following procedure is recommended for the actual source preparation:

- a. Express 25 $\mu$ l (0.025 ml) of active solution on the center of the 5/8 inch diameter metallic coated parafilm film. The micropipette should be rinsed twice

[illegible]

The fact that the writer has been able to do so much work in such a short time is due to the fact that he has been able to devote his entire time to it.

[illegible]

The following schedule is recommended for the year

... (a) ... (b) ... (c) ... (d) ... (e) ... (f) ... (g) ... (h) ... (i) ... (j) ... (k) ... (l) ... (m) ... (n) ... (o) ... (p) ... (q) ... (r) ... (s) ... (t) ... (u) ... (v) ... (w) ... (x) ... (y) ... (z) ...

onto the source ring in order to remove all active material from the pipette. It has been experimentally determined that the following percentages of active material are contained in rinses of the pipette: PIPETTE

1st rinse — 3 percent of initial contents

2nd rinse — 1 percent of initial contents

3rd rinse — 0.5 percent of initial contents

Micropipettes\* used in source preparation must be calibrated with mercury since deviations of 1 percent from labeled volume are not uncommon. TO VACUUM PUMP

b. If several sources are to be prepared at a time, the vacuum trap arrangement illustrated in Fig. 7 is indispensable. After each source (consisting of one pipette volume plus two rinses) is expressed, the pipette must be thoroughly cleaned and dried prior to preparing the next source. Using the vacuum trap arrangement the pipette can be cleaned with an inactive carrier solution followed by flushing with pure distilled water and then dried by the air stream pulled through the pipette. VACUUM TRAP ARRANGEMENT FOR CLEANING AND DRYING  
FIGURE 7  
The total operation of cleaning and drying requires less than 3 minutes with this apparatus.

c. Express 10 $\mu$ l of Bentonite solution (approximately 25 mg Bentonite/ml H<sub>2</sub>O) into the drop of source

\* Obtainable from Radiation Counter Lab., 1844 W. 21st St., Chicago, Ill.



into the source that is used in forming all active  
material from the cigarette. It has been experimentally  
determined that the following percentage of active  
material are contained in cases of the cigarette:

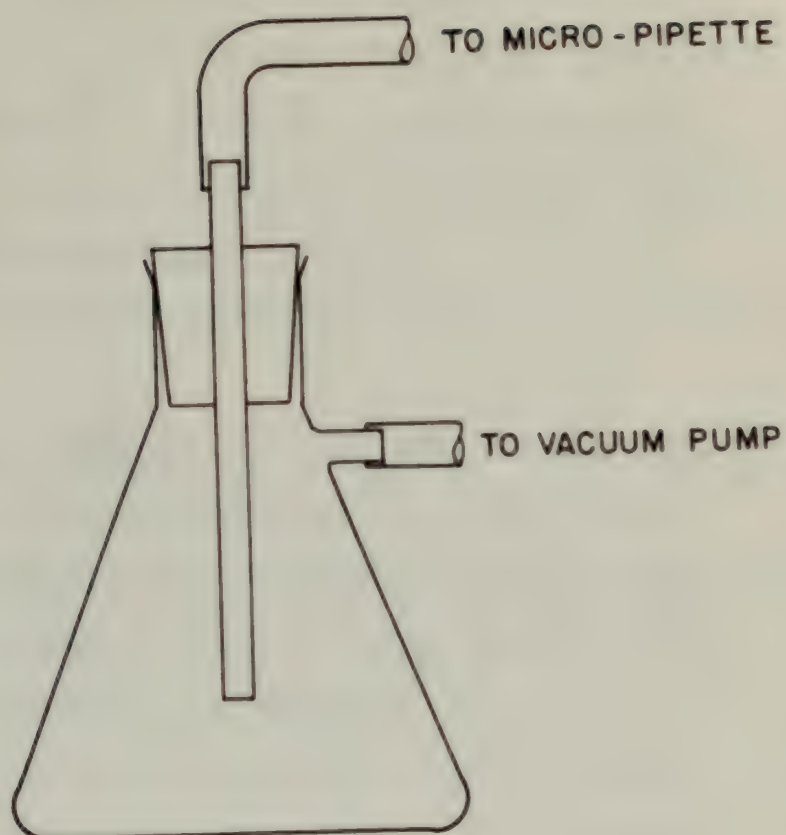
- 1st class -- 1 percent of initial cigarette
- 2nd class -- 1 percent of initial cigarette
- 3rd class -- 0.5 percent of initial cigarette

It is important to note in making this statement that the  
cigarette with active material contained in it is not  
from the active material of the cigarette.

It is further stated that the percentage of  
active material contained in the cigarette is  
1.5 percent of the initial cigarette. It is further  
stated that the active material contained in the cigarette  
is not the same as the active material contained in the  
cigarette. It is further stated that the active material  
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It is further stated that the active material contained  
in the cigarette is not the same as the active material  
contained in the cigarette. It is further stated that the  
active material contained in the cigarette is not the same  
as the active material contained in the cigarette.





VACUUM TRAP ARRANGEMENT FOR  
CLEANING AND DRYING PIPETTES

Figure 7



solution previously formed.

d. Thoroughly disperse the Bentonite in the source solution using an air jet produced from an eye-dropper which has been flame-drawn to a fine capillary point. A strong light facilitates visual observation of the mixing which is complete when the entire drop takes on a cloudy appearance.

e. The prepared source is then dried under a heat lamp.

2. Isotopes emitting  $\beta$  particles of  $\leq 0.4$  Mev.

In order to minimize self-absorption losses in the measurement of soft  $\beta$  particles extreme care must be taken in preparation of the thin source, especially if the isotope solution is a chloride which tends to form large crystals on precipitation. The following procedure, applicable to preparation of  $\text{Co}^{60}$  sources, is cited as an example.<sup>(8)</sup>

a. Using  $\text{Co}^{60}$  of high activity (approximately 1 curie/gram), dilute to proper operating range using redistilled HCl. The solid content of ordinary HCl often exceeds the solid content of the source material. The carrier concentration should be of the order of 3 mg of  $\text{CoCl}_2$ /liter giving a total solid content in a 25 $\mu$ l aliquot of 0.075  $\mu$ g.

relative pressure, however.

4. Theoretical discussion: The conditions in the  
source medium being an air jet pressure from an ex-  
posed which has been determined as a time history  
point. A strong light radiation from the medium  
of the mixed which is coupled with the entire flow  
takes on a clearly appearance.

5. The proposed source is then called under a  
new name.

6. Theoretical analysis: The conditions in the  
in the medium of the source are determined as a  
function of the properties of the medium, especially  
if the source medium is a mixture which leads to  
then the source is considered. The following  
assumptions, applicable to the properties of the source,  
is cited as an example. (9)

7. When the source is active (non-steadily  
active), there is a source pressure wave  
reflected back. The wave is called a pressure wave.  
The source is the source of the source pressure.  
The source is considered as a source of the source  
as a source of the source pressure in a  
source of 0.075 kg.



b. After pipetting the required amount of active solution on the source film, evaporate the  $\text{Co}^{60}$  to dryness as  $\text{CoCl}_2$  in order to get rid of the  $\text{HCl}$ . Then add a drop of water to the evaporated material to redissolve the  $\text{CoCl}_2$ .

c.  $\text{NH}_3$ , introduced as  $\text{NH}_4\text{OH}$  in a beaker, should be used to precipitate the cobalt which should cover the entire area of the original water drop quite uniformly.

Steps (b) and (c) above should be done in a desiccator with sodium hydroxide used as a desiccant. A  $\text{Co}^{60}$  source carefully prepared as outlined above will reduce self-absorption to the minimum value known to be obtainable at this time.

plotted for counter voltages of 300, 400, and 500 volts (Figs. 10 and 11). If in both cases the discrimination curves are flat over a discriminator range of  $\geq$

10 volts (Fig. 10), we can assume that all  $\beta$  particles emitted from the positive voltage are being counted.

### 1. Sources.

Normally three sources are prepared as outlined in Section F from each solution to be counted. Comparison of counting rates of the three sources gives a measure of the precision in source preparation. With a little care and of extrapolation to zero time the true

1. After receiving the required amount of  
positive reaction on the surface of the  
to be tested, in order to get rid of the  
from the surface of the surface of the  
relative to the surface of the surface of the  
to be tested, in order to get rid of the  
from the surface of the surface of the  
relative to the surface of the surface of the

be obtainable at this time.

I have been thinking about you very much lately and wondering how you are getting on. I hope you are well and happy.

practice the difference between sources due to all errors involved in preparation may be maintained at  $< 1$  percent.

## 2. Counting procedure.

Background counts are taken before (and after if necessary) each run by inserting a plain shin steel disc in place of the source. Two comparison tests are made on all measurements made with the 4 $\pi$  counter. First, with counter voltage fixed at 4300 volts, integral discriminator curves are plotted for gain settings of 10:1, 9:1, and 8:1. The latter two settings each decrease electronic gain by a factor of approximately 2 (Figs. 8 and 9). Secondly, with electronic gain held constant at 10:1, integral discriminator curves are plotted for counter voltages of 3900, 4100, and 4300 volts (Figs. 10 and 11). If in both cases the discriminator curves are flat over a discriminator range of  $\geq 10$  volts (Fig. 12), we can assume that all  $\beta$  particles emitted into the sensitive volume are being counted. Figures 9 and 11 which are typical of  $\text{Co}^{60}$  clearly indicate the high percentage of collection and may be compared with Figs. 8 and 10 which are typical of  $\text{P}^{32}$ . The method of extrapolation to determine the true



translates the difference between systems due to all  
errors involved in observation may be estimated at  
< 1 percent.

## 1. General discussion.

Background counts are taken before (and after  
if necessary) each run by inserting a plain zinc sheet  
into the place of the source. Two comparisons have been  
made on all measurements with the 10 counter.  
First, with counter voltage fixed at 400 volts, in-  
serted aluminum source and placed for each reading  
of 100, 200, and 400. The latter two settings were  
taken at electronic gain of a factor of approximately 3  
(Fig. 8 and 9). Usually, with electronic gain held  
constant at 100, inserted aluminum source was  
checked for counter voltage of 100, 200, and 400  
volts (Fig. 10 and 11). It is felt that the electronic  
gain errors are less than a statistical range of  $\pm 2$   
in volts (Fig. 12), so we assume that all 7 particles  
collected into the sensitive volume are being counted.  
Figures 8 and 11 which are typical of the  $^{60}\text{Co}$  decay indi-  
cate the high percentage of collection and may be com-  
pared with Fig. 8 and 10 which are typical of  $^{137}\text{Cs}$ .  
The method of extrapolation to determine the true



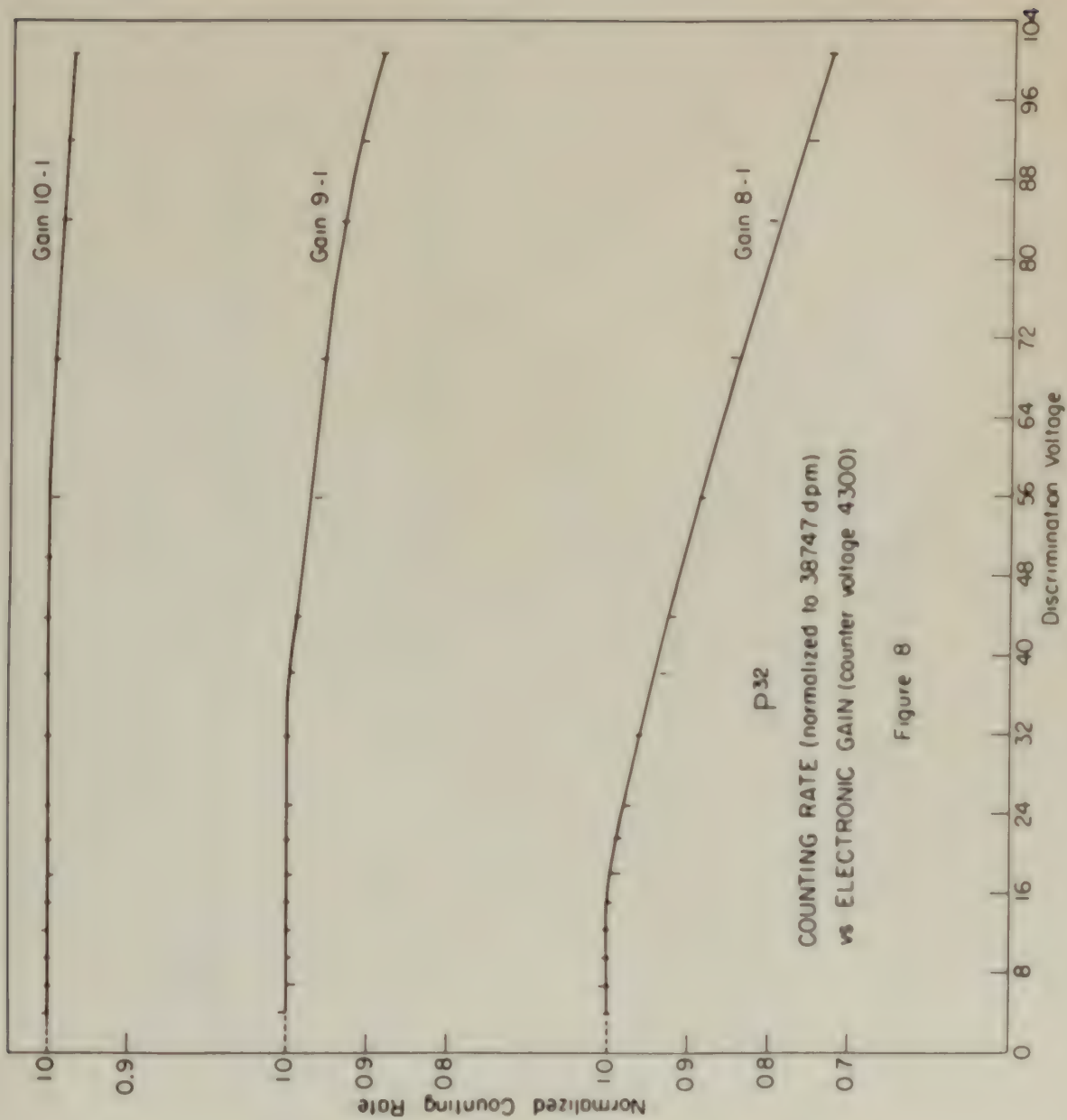
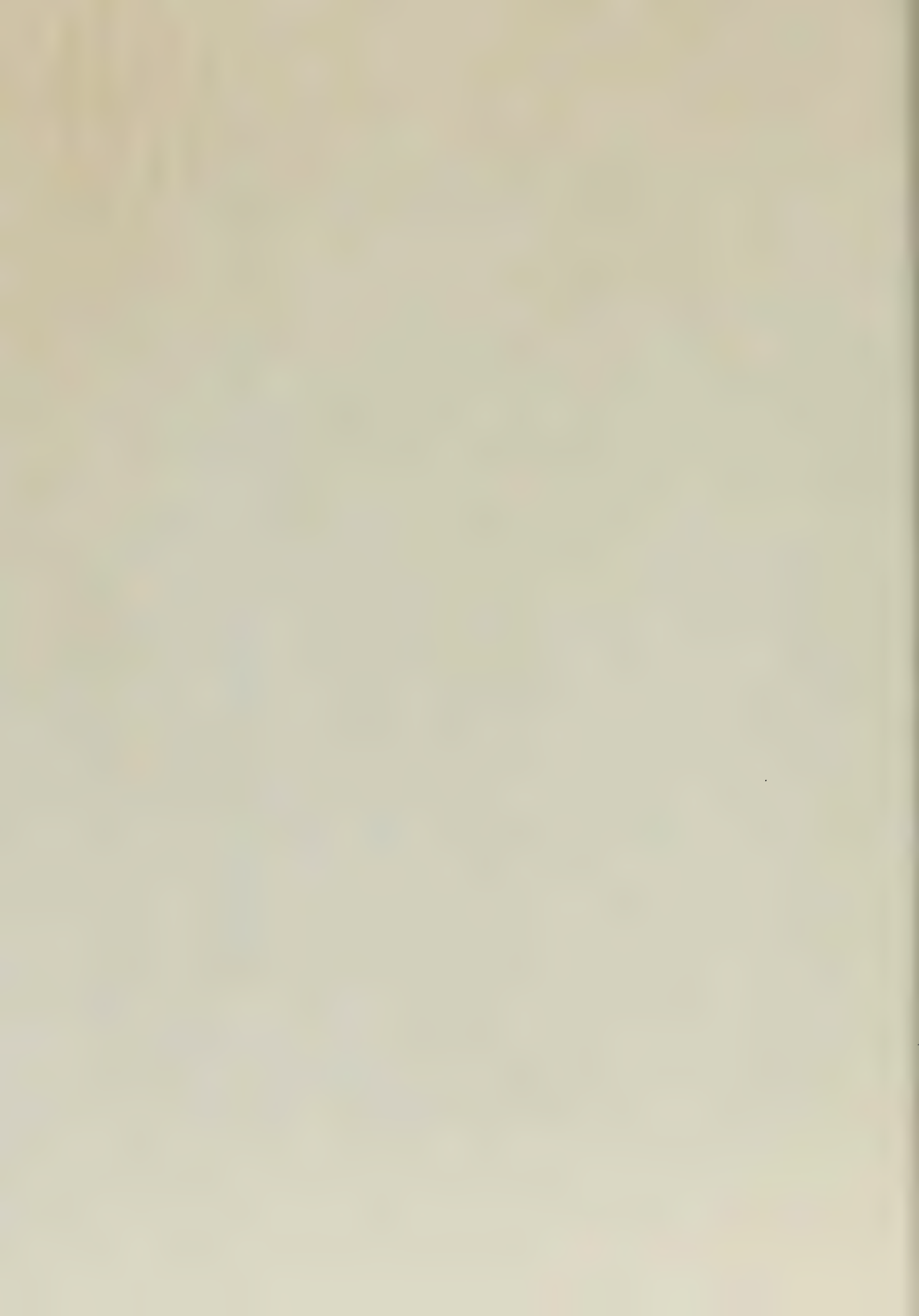


Figure 8



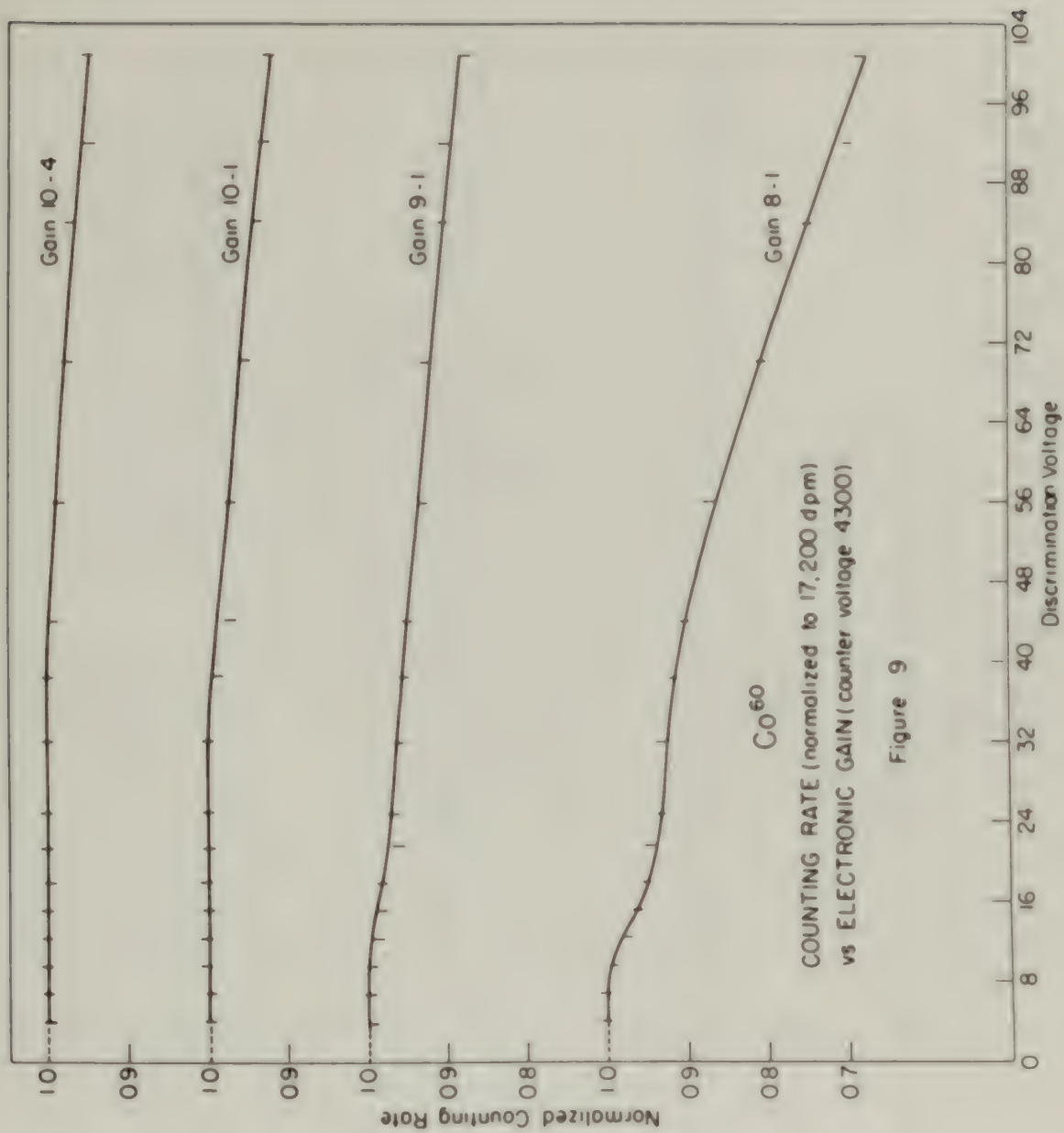
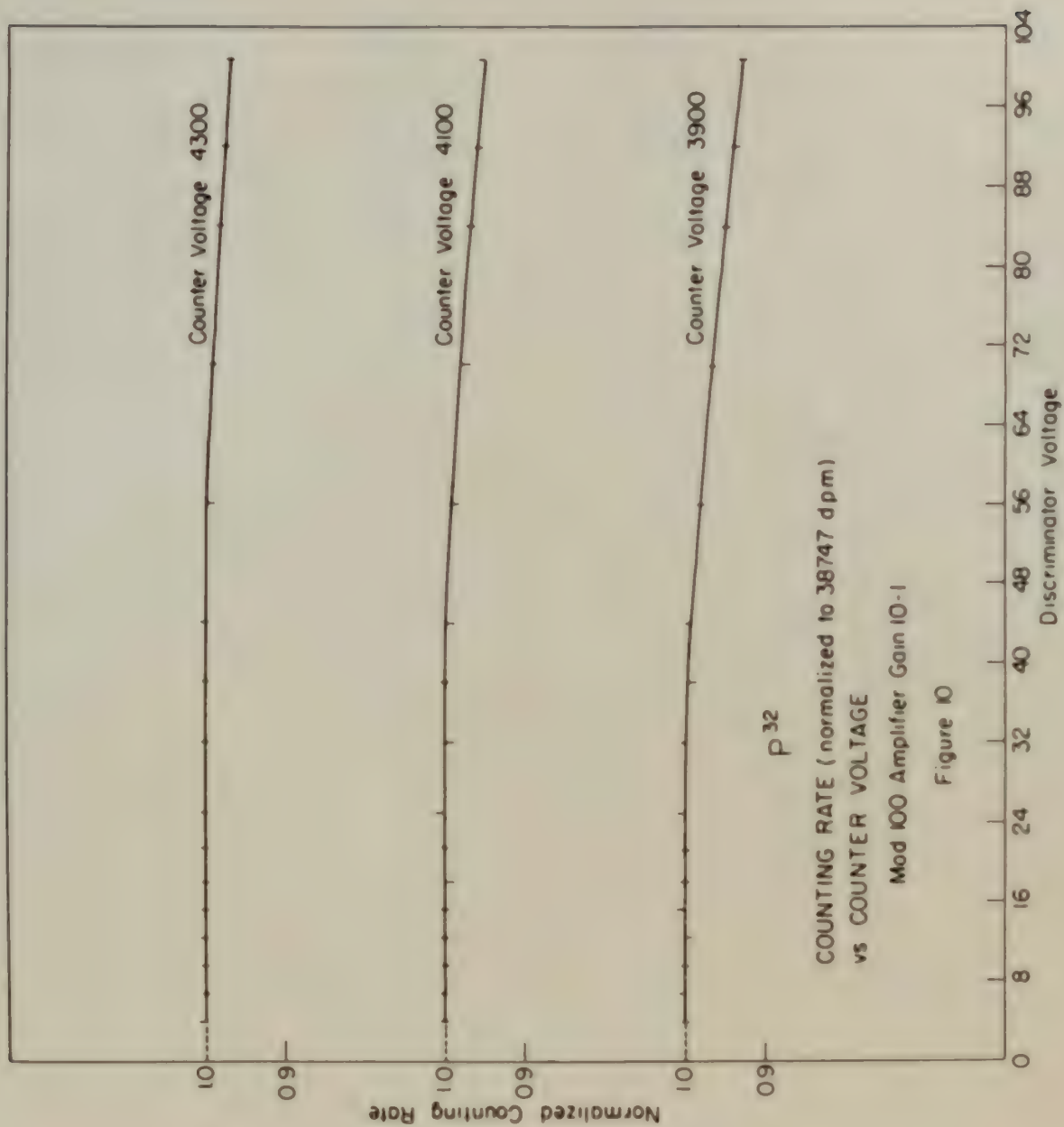


Figure 9









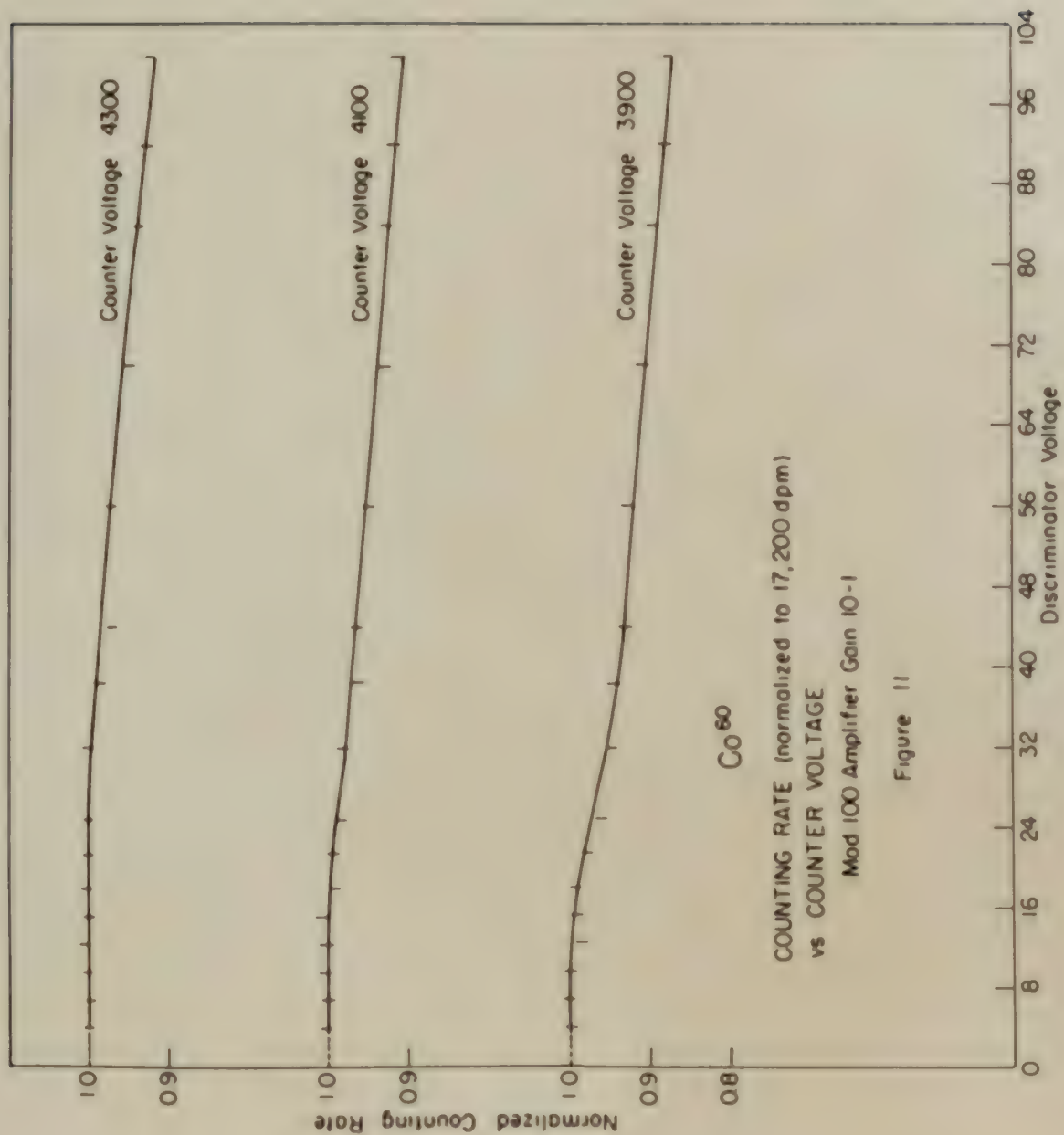


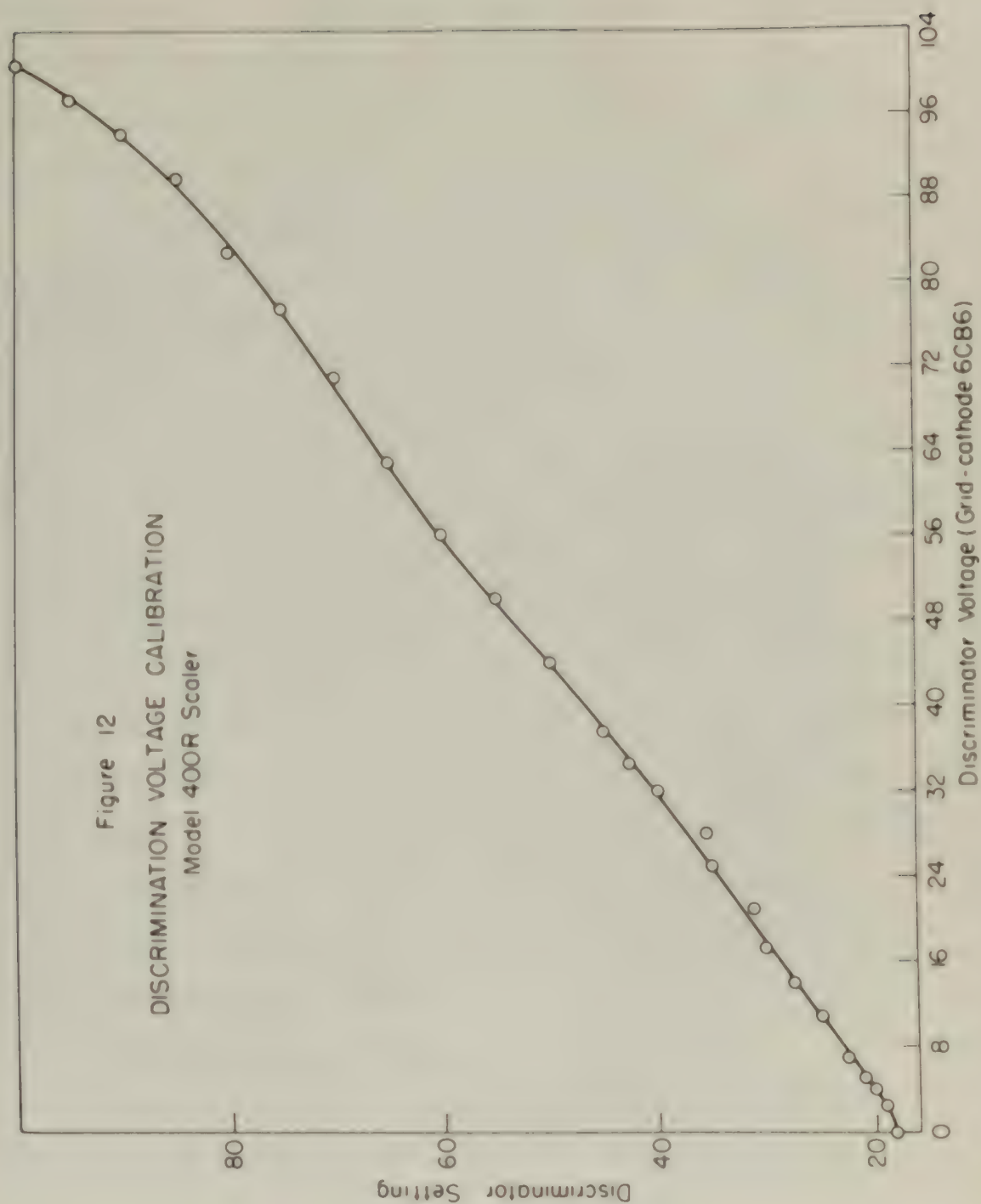
Figure 11





Figure 12

DISCRIMINATION VOLTAGE CALIBRATION  
Model 400R Scaler





disintegration rate is indicated on all curves. A further check to verify proper operation is a statistical analysis of the counting rates for points on the discriminator plateau. The mean value thus obtained should agree with the extrapolated true counting rate.

Once the voltage range of the discriminator plateau has been determined for a given isotope the counting procedure is simplified. The discriminator may then be set at the midpoint of the voltage plateau and with counter voltage set at 4500 volts and an electronic gain of 10:1, a series of runs is made. A statistical analysis of these runs is then made to insure that the counter is operating properly and the observed counting rate is determined by the mean value thus obtained.

An electronic gain of 10:1 is chosen as the normal operating point. At this value the largest pulses in the counter just overdrive the Model 100 amplifier without causing counting losses, and the smallest pulses are sufficiently larger than noise to be detectable over a useful discriminator range.

### 3. Correction to observed counting rate.

The average background is subtracted from the mean value of the measured counting rate, to yield  $N_0$ ,

investigation was conducted on all cases. A  
 further search is being made in a systematic  
 manner of the existing cases for points in the  
 various classes. The work will then be  
 done with the unclassified case counting rate.  
 Once the value range of the unclassified cases  
 has been determined a given type of the counting  
 procedure is simplified. The classification may then be  
 set at the midpoint of the value range and with  
 counter value set at 1000 with an electronic gain  
 of 100, a series of runs is made. A statistical analysis  
 of these runs is then made to insure that the counting is  
 operating properly and the observed counting rate is  
 determined by the mean value from several.  
 An electronic gain of 100 is chosen as the normal  
 operating value. At this value the largest pulse in  
 the counter just exceeds the Model 100 amplifier output  
 causing counting losses, and the smallest pulse is  
 sufficiently large that there is no appreciable zero or  
 useful discrimination range.

3. **Estimation of statistical counting rate.**  
 The average background is subtracted from the  
 mean value of the measured counting rate, to yield  $\bar{R}_0$



the observed counting rate. For counting rates  $\leq 60,000$  dpm, this value may be used as  $R_t$ , the true disintegration rate, if an error of 1 percent is acceptable.

Any or all of the following corrections may be made depending on the degree of precision desired:

a. Correction for resolving time losses. If  $N_o$  and  $N_A$  are defined respectively as observed and actual disintegration rates, then

$$N_A = \frac{N_o}{1 - N_o t}$$

when  $t$  is the counter resolving time which has been determined to be approximately 20 nsec.

b. Correction for absorption due to source mounting film. If it is desired to make this correction, then at the same time the source mountings are prepared, cover layers of parlodion film of the same thickness should be prepared on source rings having a central hole of 1 3/8 inch diameter. The conducting film evaporated on these cover layers should be of the same thickness as that deposited on the ring containing the active source.

With the active source in place obtain  $N_{A1}$ , the actual counting rate. Then remove the source ring,



carefully place the ring containing the cover layer directly over the source to form a sandwich. With this sandwiched source in place, again measure  $N_{A_2}$ .

The percentage difference in  $N_{A_1}$  and  $N_{A_2}$  should be quite close to the true correction for absorption due to the mounting film.

A slightly more accurate determination of absorption in the mounting film<sup>(7)</sup> is quoted below for completeness.

Experiments have been conducted to determine the amount of absorption, if any, due to the film between the source and the lower half of the 4π counter. The number of particles counted by the top half of the counter connected separately will be

$$N_{\text{top}} = \frac{N_0}{2} [1 + B_f + (1 - \tau) B_w(b)] \quad (1)$$

where  $N_0$  is the true disintegration rate of the source,  $B_f$  is the percentage backscattering from the film,  $\tau$  is the fractional absorption in the film, and  $B_w(b)$  is the percentage backscattering due to the walls in the bottom half. The number of particles counted by the bottom half connected separately will be

$$N_{\text{bottom}} = \frac{N_0}{2} [(1 - \tau) + (1 + B_f) B_w(t)] \quad (2)$$



carefully place the ring containing the silver layer directly over the source so that a substance with this characteristic source is placed at its center. The percentage difference in  $\lambda_1$  and  $\lambda_2$  should be quite small in the first conversion the absorption due to the remaining film.

A slightly more accurate determination of absorption in the remaining film is made before the completion. Experiments have been conducted to determine the amount of absorption, it may, due to the film between the source and the lower half of the counter. The number of particles counted by the top half of the counter connected separately will be

$$N_{top} = \frac{1}{2} [1 + \lambda_1 - (1 - \lambda_1) N_0] \quad (1)$$

where  $\lambda_1$  is the true absorption rate of the source,  $N_0$  is the percentage counter-efficiency from the film, is the fractional absorption in the film, and  $N_0$  is the percentage counter-efficiency due to the film in the lower half. The number of particles counted by the bottom half connected separately will be

$$N_{bottom} = \frac{1}{2} [1 + \lambda_2 - (1 - \lambda_2) N_0] \quad (2)$$



\*From symmetry considerations  $B_V(t) = B_V(b) = B_V$ .

\*The factor  $B_V$  can be neglected when the film is thin and of low atomic number, so that (1) becomes

$$N_{top} = \frac{N_0}{2}(1 + B_V - \tau B_V) \quad (3)$$

In the bottom half, again assuming  $B_V = 0$ , one obtains

$$N_{bottom} = \frac{N_0}{2}[(1 - \tau) + B_V] \quad (4)$$

Putting this in the form  $y = ax + b$  gives

$$N_{bottom} = \frac{-N_0}{2} \tau + \frac{N_0}{2}(1 + B_V). \quad (5)$$

\*With the thin films under consideration it can be assumed that the absorption is directly proportional to the film thickness. Equation (5) can be used to determine the absorption correction graphically. A more direct method of determining  $\tau$  can be deduced from eq. (3) and (4).

$$N_{top} - N_{bottom} = \frac{N_0}{2} \tau (1 - B_V). \quad (6)$$

The actual counting rate observed with top and bottom halves connected together is

$$N_{th} = N_0(1 - \tau/2) \quad (7)$$

so that (6) becomes, if one lets  $N_{top} - N_{bottom} = \Delta$

From symmetry considerations  $H_y(t) = H_y(0) = H_0$ .  
 The factor  $H_0$  can be neglected since the film is  
 thin and at low atomic number, so that (1) becomes

$$(1) \quad H_{top} = \frac{H_0}{2}(1 + \tau - \tau H_0)$$

In the bottom half, again assuming  $H_0 = 0$ , one obtains

$$(2) \quad H_{bottom} = \frac{H_0}{2} \left[ (1 + \tau) + H_0 \right]$$

Putting this in the form  $\gamma = \alpha + \beta$  gives

$$(3) \quad H_{bottom} = \frac{H_0}{2} \left[ 1 + \frac{H_0}{2}(1 + \tau) \right]$$

With the thin film model approximation it can  
 be assumed that the absorption is directly proportional  
 to the film thickness. Equation (3) can be used to  
 determine the absorption correction factor. A  
 more direct method of determining  $\tau$  can be obtained  
 from eqs. (1) and (2).

$$(4) \quad H_{top} - H_{bottom} = \frac{H_0}{2} (1 - H_0)$$

The actual measured ratio obtained with top and bottom  
 films corrected together is

$$(5) \quad H_{top} = H_0(1 - \tau)$$

so that (4) becomes, if one takes  $H_{top} = H_{bottom} = \Delta$

$$\tau = \frac{N_{top} - N_{bottom}}{N_{tb} - N_b} = \frac{\Delta}{N_{tb} - N_b} \quad (8)$$

and similarly

$$B_V = \frac{N_{top} + N_{bottom}}{N_{tb}} - 1. \quad (9)$$

The absolute counting rate is then obtained by substituting (8) into

$$N_o = \frac{N_{tb}}{1 - \tau/B}. \quad (10)$$

"Thus by taking three different readings of the same source on a single film it is possible to determine the absorption by the film. This proves extremely useful for low energy  $\beta$  particles."

c. Corrections for self-absorption and back-scattering due to finite source thickness. In general the sources prepared are very thin compared with the half thickness for  $\beta$  absorption in source material. Since the resultant self-absorption and backscattering corrections are small (usually < 1 percent), approximate methods may be used to compute these corrections. The average source thickness is computed from the source area and the known mass of material contained therein.

Self-absorption may be estimated as follows:



$$(c) \quad \frac{\Delta}{\Delta} = \frac{\Delta}{\Delta} = \frac{\Delta}{\Delta}$$

and similarly

$$(d) \quad \frac{\Delta}{\Delta} = \frac{\Delta}{\Delta} = \frac{\Delta}{\Delta}$$

The average reaction rate is then obtained by

averaging (8) into

$$(e) \quad \frac{\Delta}{\Delta} = \frac{\Delta}{\Delta} = \frac{\Delta}{\Delta}$$

Thus by using these different methods of the same

method on a single film it is possible to determine the

absorption of the film. This method is usually used

for low energy particles.

2. Determination of self-absorption and self-

scattering in thin films. In general

the method proposed and used here depends on the

self-absorption for a specimen in a given material.

Since the reaction self-absorption and self-scattering

corrections are small (usually < 1 percent), approxi-

mate methods may be used to measure these corrections.

The average reaction thickness is computed from the curve

area and the known mass of material contained therein.

Self-absorption may be estimated as follows:



Let  $t$  = half thickness for  $\beta$  in source material  
(in  $\mu\text{g}/\text{cm}^2$ )

$\bar{x}$  = average source thickness (in  $\mu\text{g}/\text{cm}^2$ )

then the true activity  $N_t$  is related to the observed activity  $N_A$  by

$$N_A \approx \frac{N_t}{\bar{x}} \int_0^{\bar{x}} \left(\frac{1}{2}\right) \left(\frac{\bar{x}}{t}\right) d\bar{x}$$

$$\frac{N_A}{N_t} = \frac{1}{\bar{x}} \left[ \frac{1 - \left(\frac{1}{2}\right) \bar{x}/t}{\ln 2} \right] = \frac{1 - \left(\frac{1}{2}\right) \bar{x}/t}{0.693}$$

and  $\frac{N_A}{N_t} \approx 1 - (0.346) \bar{x}/t$  for  $\bar{x} \ll t$

If desired, backscattering corrections may be approximated from the results published by Zumwalt.<sup>(9)</sup> In these corrections it is assumed that when the source mounting material is very thin, the percentage of saturation backscattering obtained is a function only of its thickness in terms of absorption half thickness. With this assumption, the Zumwalt data obtained for polystyrene can be applied to parlodion by comparing relative half thicknesses involved.

There is also a small loss for particles which travel transversely through the film and are absorbed



before emerging. An order of magnitude approximation of this loss can be made by consideration of the solid angle within which particles will traverse one half-thickness of the film before emerging. For  $P^{32}$  (assuming a half thickness of about  $100 \text{ mg/cm}^2$ ) this gives, for a uniform film  $0.05 \text{ mg/cm}^2$  thick:

$$\delta \Omega \sim \frac{2\pi \times \frac{0.05}{100}}{4\pi} \approx \frac{1}{4000}$$

where  $\delta \Omega$  = the fraction of emergent particles which traverse a path  $\geq$  one half-thickness of the film, which is negligible. For softer  $\beta$  particles, this correction may be large enough to require consideration.

#### H. Important Characteristics of 4 $\pi$ Counter

Counter voltage plateau: begins at 3700 volts, slope  $< 0.8$  percent per 100 volts.

#### Settings for normal operation:

Counter voltage: 4300 volts

Cathode: 2500 volts below ground, 600 volts supplied by batteries.

Center wires and guard rings: 1500 volts above ground.



[illegible]

5. 12. 1922

Since  $\Omega$  is the limit of  $\Omega_n$  as  $n \rightarrow \infty$ , it follows that  $\Omega$  is a limit of  $\Omega_n$  as  $n \rightarrow \infty$ . This is the desired result.

SECRET NO 10

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Figure 2.6: A plot of the function  $f(x) = x^2$  for  $x \in [0, 1]$ . The function is a parabola starting at (0,0) and ending at (1,1).

1984-1985

29 Nov 60 10:45 AM

Chlorophyll *a* and carotenoid contents were determined by spectrophotometry using the method of Lichtenthaler and Whaley (1983).

*Submitted by*

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• **Liberty**



Electronic gain (Model 100 amplifier, Atomic Instrument Co. preamplifier Model 204B):

Coarse gain: 10

Fine gain: 1

Resolving time:  $20 \pm 5 \mu\text{sec}$  (determined by a series of measurements by the two-source method)

n-butane flow gas rate: approximately 2 bubbles/sec

Flushing time required for stable operation: 20 min

Length of discriminator plateau (at normal operating settings):

$\text{Co}^{60}$  25 volts

$\text{I}^{131}$  30 volts

$\text{P}^{32}$  50 volts

Counter efficiency:

$\text{Co}^{60} \approx 87$  percent (due to high solid content of available  $\text{Co}$  activity)

$\text{I}^{131} \geq 98$  percent

$\text{P}^{32} \geq 99$  percent

The following table shows the results of the tests conducted on the various samples of the material under investigation. The results are given in terms of the percentage of material which is soluble in the various solvents used. The results are given in the following table:

Solvent	Percentage Soluble
Water	100
Alcohol	100
Ether	100
Chloroform	100
Benzene	100
Carbon tetrachloride	100
Acetic acid	100
Sulfuric acid	100
Nitric acid	100
Hydrochloric acid	100
Sodium hydroxide	100
Potassium hydroxide	100
Ammonia	100
Hydrogen peroxide	100
Hydrogen sulfide	100
Sulfur dioxide	100
Nitrogen dioxide	100
Oxygen	100
Hydrogen	100
Carbon monoxide	100
Carbon dioxide	100
Water vapor	100
Alcohol vapor	100
Ether vapor	100
Chloroform vapor	100
Benzene vapor	100
Carbon tetrachloride vapor	100
Acetic acid vapor	100
Sulfuric acid vapor	100
Nitric acid vapor	100
Hydrochloric acid vapor	100
Sodium hydroxide vapor	100
Potassium hydroxide vapor	100
Ammonia vapor	100
Hydrogen peroxide vapor	100
Hydrogen sulfide vapor	100
Sulfur dioxide vapor	100
Nitrogen dioxide vapor	100
Oxygen vapor	100
Hydrogen vapor	100
Carbon monoxide vapor	100
Carbon dioxide vapor	100

The results of the tests conducted on the various samples of the material under investigation are given in the following table:

Solvent	Percentage Soluble
Water	100
Alcohol	100
Ether	100
Chloroform	100
Benzene	100
Carbon tetrachloride	100
Acetic acid	100
Sulfuric acid	100
Nitric acid	100
Hydrochloric acid	100
Sodium hydroxide	100
Potassium hydroxide	100
Ammonia	100
Hydrogen peroxide	100
Hydrogen sulfide	100
Sulfur dioxide	100
Nitrogen dioxide	100
Oxygen	100
Hydrogen	100
Carbon monoxide	100
Carbon dioxide	100

The results of the tests conducted on the various samples of the material under investigation are given in the following table:

Solvent	Percentage Soluble
Water	100
Alcohol	100
Ether	100
Chloroform	100
Benzene	100
Carbon tetrachloride	100
Acetic acid	100
Sulfuric acid	100
Nitric acid	100
Hydrochloric acid	100
Sodium hydroxide	100
Potassium hydroxide	100
Ammonia	100
Hydrogen peroxide	100
Hydrogen sulfide	100
Sulfur dioxide	100
Nitrogen dioxide	100
Oxygen	100
Hydrogen	100
Carbon monoxide	100
Carbon dioxide	100

The results of the tests conducted on the various samples of the material under investigation are given in the following table:

Solvent	Percentage Soluble
Water	100
Alcohol	100
Ether	100
Chloroform	100
Benzene	100
Carbon tetrachloride	100
Acetic acid	100
Sulfuric acid	100
Nitric acid	100
Hydrochloric acid	100
Sodium hydroxide	100
Potassium hydroxide	100
Ammonia	100
Hydrogen peroxide	100
Hydrogen sulfide	100
Sulfur dioxide	100
Nitrogen dioxide	100
Oxygen	100
Hydrogen	100
Carbon monoxide	100
Carbon dioxide	100

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APPENDIX II

THE SCINTILLATION  $\gamma$ -RAY SPECTROMETER

The spectrometer consists of a sodium iodide scintillator activated crystal 4.3 cm in diameter and 8 cm long mounted on an aluminum base. The data of the detector sensitivity have been reported in Table I. The detector is connected to a voltage divider of 100  $\Omega$  to 100 volts. A single channel differential pulse height analyzer, the Model 1000, is driven by a 100-volt power supply. The output of the analyzer is connected to a 100-volt power supply. The discriminator base line is varied continuously from approximately 0 to 100 volts and a signal of 8 volts is used for all observations. Calibration runs were made before and after obtaining each set of data by use of  $\gamma$ -emitters of known energy.

The Commission on the Status of Women  
has the honor to acknowledge the receipt of  
your letter of the 10th inst. and in reply  
to inform you that the same has been  
forwarded to the appropriate authorities  
for their consideration.

Very respectfully,  
The Secretary

THE COMMISSION ON THE STATUS OF WOMEN  
has the honor to acknowledge the receipt of  
your letter of the 10th inst. and in reply  
to inform you that the same has been  
forwarded to the appropriate authorities  
for their consideration.



## APPENDIX II

### THE SCINTILLATION $\gamma$ -RAY SPECTROMETER

The counter consists of a sodium iodide thallium activated crystal 4.3 cm in diameter and 5 cm long mounted on an RCA type 6210 photomultiplier tube. The gain of the linear amplifier used is adjusted so that the spectrum is always represented by voltage pulses of from 0 to 100 volts. A single channel differential pulse height analyzer, fed by the linear amplifier, drives a precision counting rate meter of variable time constant and full-scale sensitivity of from 200 to 20,000 counts per minute. The discriminator base line is varied continuously from approximately 0 to 100 volts and a window of 2 volts is used for all observations. Calibration runs were made before and after obtaining each set of data by use of  $\gamma$ -emitters of known energy.

THE CRISTALINE - LAY EXPERIMENT

The experiment consisted of a series of tests in which  
 a crystal of quartz was placed in a circuit with a battery  
 and a galvanometer. The crystal was cut in a special way  
 so that it would give a definite deflection of the galvanometer  
 when it was placed in the circuit. The deflection was  
 measured and the results were compared with the theoretical  
 values. The experiment was repeated several times and the  
 results were found to be in good agreement with the theory.  
 The experiment was also repeated with crystals of different  
 sizes and shapes and the results were found to be in good  
 agreement with the theory. The experiment was also repeated  
 with crystals of different materials and the results were  
 found to be in good agreement with the theory. The experiment  
 was also repeated with crystals of different thicknesses and  
 the results were found to be in good agreement with the theory.  
 The experiment was also repeated with crystals of different  
 shapes and the results were found to be in good agreement  
 with the theory. The experiment was also repeated with  
 crystals of different materials and the results were found to  
 be in good agreement with the theory. The experiment was  
 also repeated with crystals of different thicknesses and the  
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 with the theory. The experiment was also repeated with  
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 also repeated with crystals of different thicknesses and the  
 results were found to be in good agreement with the theory.

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OF THE

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1842

1843

1844

1845

1846

1847



### APPENDIX III

#### THE END WINDOW 3 COUNTER

counts per 1 minute interval. The counter was used for at least three intervals. At intermediate counting rates, the

#### A. Description of Equipment

The tube was operated at the mid-point of its range. This equipment, used in determining  $\beta$  energies, consists of a conventional end window Geiger-Müller tube\* and a set of calibrated aluminum absorbers.\*\* The tube is mounted in a shielded sample changer\*\*\* which contains sliding trays for accurate positioning of source and absorber.

#### C. Correction of Counting Rate

#### B. Experimental Technique

After zero counting for sources on absorber, with a source inserted on the lower tray under the Geiger tube counting rates were recorded for various thicknesses of absorber contained on the upper tray.

---

\* Tracerlab, Inc. Model TC-CH Geiger Tube, window thickness 2 mg/cm<sup>2</sup>.

\*\* Tracerlab, Inc. Type B-3A Calibrated Absorbers.

\*\*\* Tracerlab, Inc. Model SC-90 Shielded Manual Sample Changer.



75

Counting procedure varied depending upon the thickness of absorber. At high counting rates, the number of counts per 1 minute interval was recorded for at least three intervals. At intermediate counting rates, the preset count feature of the scaler was utilized and the time required for 10,000 counts was recorded. At very low counting rates, a preset count of 4000 was used.

The tube was operated at the mid-point of its voltage plateau to insure maximum stability. In addition a set of five standardized  $\beta$  emitters of known energy was periodically counted thus enabling the correction of observed counting rates for any changes in instrument sensitivity.

### C. Corrections of Observed Data

Other than correcting for counter sensitivity fluctuations mentioned above, the only correction required was for resolving time losses. These corrections were made by adding to the observed counting rates the number of lost counts per minute (Fig. 2).



Counting procedure varied depending upon the thickness of absorber. At high counting rates, the number of counts per 1 minute interval was reported for at least three intervals. At intermediate counting rates, the present count followed by the next was utilized and the time required for 10,000 counts was recorded. At very low counting rates, a gross count of 1000 was used. The tube was operated at the end-point of its voltage range in order to obtain stability. In addition a set of five standardized sources of known activity was periodically counted thus enabling the correction of observed counting rates for any changes in instrument sensitivity.

### C. Corrections of Observed Data

Other than correcting for counter sensitivity fluctuations mentioned above, the only correction applied was for resolving time losses. These corrections were made by adding to the observed counting rates the number of lost counts per minute (Fig. 1).



### B. Resolving Time Losses

It is generally assumed that the resolving time of an instrument is constant for all counting rates and corrections are usually made for resolving time losses by means of equations derived on the basis of two general counter types; the paralyzable and the non-paralyzable. A detailed treatment of these two cases\* results in the following equations:

$$n = N e^{-Np} \quad (\text{paralyzable type}) \quad (1)$$

$$n = N(1 - np) \quad (\text{non-paralyzable type}) \quad (2)$$

At low counting rates both equation (1) and equation (2) reduce to

$$N = n(1 + np) \quad (3)$$

where  $N$  and  $n$  are respectively the true and observed counting rates and  $p$  is the resolving time.

In this experiment it was considered necessary at times to count at very high rates ( $\sim 50,000$  cpm) because of the possible presence of short-lived isotopes and the desire to obtain complete sets of absorption data as quickly as possible. It was obvious that the approximate equation (3) could not be used and it was also found that

---

\* Evans, R. D.: Class Notes for Course 8.512, Chapter 30.

### 3. Resolving Time Issues

It is generally assumed that the resolving time of

an instrument is constant for all counting rates and  
 corrections are usually made for resolving time losses  
 by means of equations derived on the basis of two  
 general counter types: the paralyzable and the non-  
 paralyzable. A detailed treatment of these two cases  
 results in the following equations:

$$(1) \quad (paralyzable \ type) \quad n = N e^{-n\tau}$$

$$(2) \quad (non-paralyzable \ type) \quad n = N(1 - n\tau)$$

It is for counting rates with equation (1) and equation (2)  
 reduce to

$$(3) \quad n = N(1 + n\tau)$$

where  $N$  and  $n$  are respectively the true and observed  
 counting rates and  $\tau$  is the resolving time.

In this equation, it was considered necessary to  
 limit the count at very high rates ( $\sim 10,000$  cps) because  
 of the possible presence of short-lived isotopes and the  
 desire to obtain accurate data at extremely low rates  
 (likely as possible). It was obvious that the approximate  
 equation (3) could not be used and it was also found that  
 \* Evans, R. L.: *Counting Rates for Nuclear Analysis*, Chapter 10.

neither equations (1) nor (2) properly corrected the observed counting rates if a constant resolving time was assumed."

To obtain a useful relation between counting rate and resolving time loss, the response of the instrument to a series of standard sources of known activity was measured and a plot made of observed vs expected counting rate (Fig. 1).<sup>\*</sup> Two response curves are shown, one for a discriminator setting of 4, the other for a setting of 6.<sup>\*\*</sup> From the curve for a discriminator setting of 4, the setting used throughout the experiment, a plot of lost counts per minute vs observed counting rate (Fig. 2) was prepared to facilitate correction of the observed data.

To verify the accuracy of this procedure, several sources were counted with discriminator settings of 4 and 6. The following tabulation of the counting rates observed and the true counting rates computed from the applicable curve of Fig. 1, shows that the computed values agree within experimental error thus indicating that consistent corrections may be made by this method.

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\* Evans, R. D.: Class Notes for Course 8.512, Chapter 30, page 15.

\*\* Data of E. Samuels, Physics Research Laboratory, Massachusetts General Hospital, Boston, Mass.



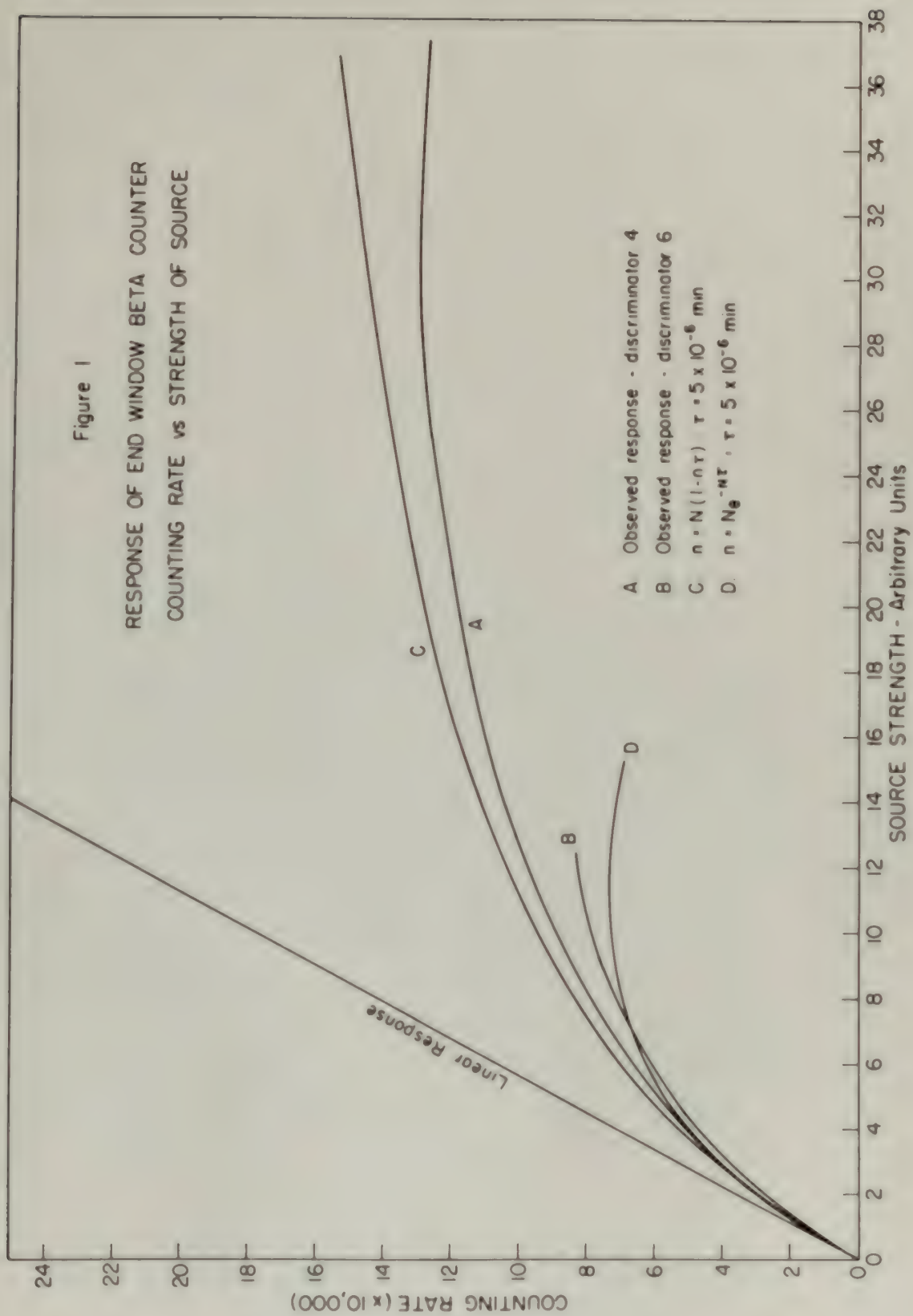
relating to the (1) and (2) subjects covered the  
observed counting rates if a constant counting rate  
was assumed. The results of the calculations are shown in  
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observed counting rates are shown in Table II. The  
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observed counting rates are shown in Table XVIII.

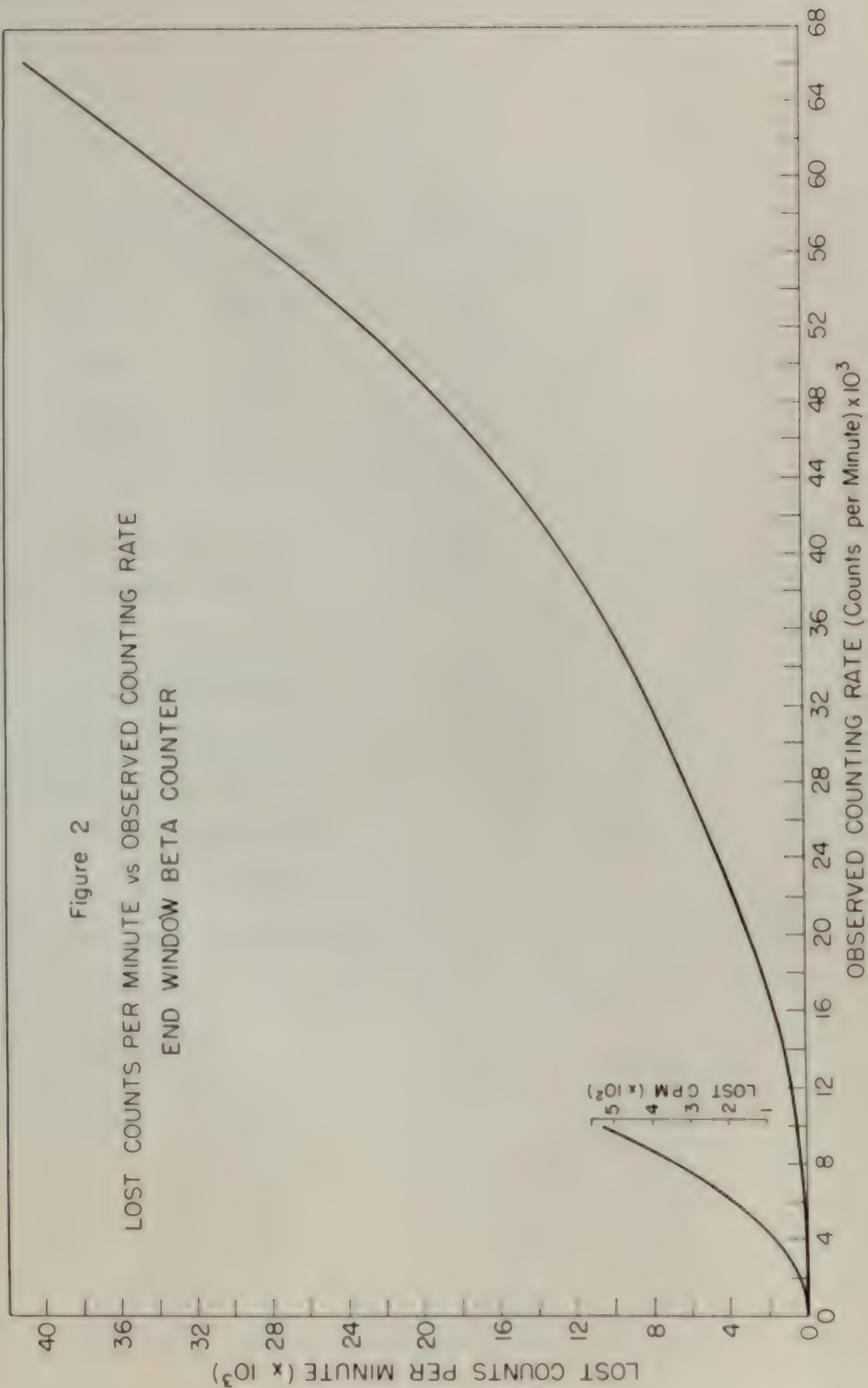


Figure 1

RESPONSE OF END WINDOW BETA COUNTER  
COUNTING RATE vs STRENGTH OF SOURCE











Observed counting rate <u>cpm</u>		Computed true counting rate <u>cpm</u>	
<u>Disc. 4</u>	<u>Disc. 6</u>	<u>Disc. 4</u>	<u>Disc. 6</u>
10580	9850	10990	10700
41350	38910	54350	53900
67600	61100	110,000	109,000

Referring to Fig. 1, it is seen that neither response curve coincides with the theoretical curves of equations (1) and (2). It is apparent that the number of lost counts is strongly dependent upon the discrimination level. The results obtained may be explained by a consideration of the pulse height distribution as a function of counting rate.\* This shows that as the counting rate is increased, many small pulses are formed and some fraction of these pulses is lost because of the discrimination level and not because of the dead time of the tube.

---

\* McCall, R. C.: "Geiger-Muller Counters", M.I.T. Progress Report, 1953.

Observed counting rate 1000		Computed from counting rate 1000	
Class A	Class B	Class A	Class B
10000	10000	10000	10000
41350	38910	54350	53800
67000	61700	110,000	108,000

Referring to Fig. 1, it is seen that neither response curve coincides with the theoretical curves of equations (1) and (2). It is apparent from the nature of the counts is strongly dependent upon the discrimination level. The results obtained may be explained by a consideration of the pulse height distribution as a function of counting rate. This shows that as the counting rate is increased, many small pulses are formed and some fraction of these pulses is lost because of the discrimination level and not because of the dead time of the tube.

## APPENDIX IV

## THE COINCIDENCE COUNTER

Left Column and Right Column		Left Column and Right Column	
Left	Right	Left	Right
Left	Right	Left	Right
Left	Right	Left	Right
Left	Right	Left	Right

## VI. CONCLUSION

The purpose of this paper is to present a new method for the determination of the concentration of a substance in a mixture. The method is based on the measurement of the optical density of the mixture at two different wavelengths. The results show that the method is very accurate and can be used for the determination of the concentration of a substance in a mixture. The method is simple and easy to use, and it does not require any special equipment. The results show that the method is very accurate and can be used for the determination of the concentration of a substance in a mixture. The method is simple and easy to use, and it does not require any special equipment.



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APPENDIX IV  
THE COINCIDENCE COUNTER

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A. Description

This equipment consists of two thallium activated sodium iodide scintillation counters connected in coincidence with single channel and coincidence scaling circuits driving mechanical registers. The crystals are 1.5 inches in diameter, 1 inch deep, and are mounted on RCA type 5819 photomultiplier tubes.

The counters are contained in lead shielded heads along with their cathode follower type preamplifiers shown schematically in Fig. 1. The two heads are mounted on a mechanical scanning device such that the two opposing crystals are coaxial and are separated by approximately 27 cm. A mounting bracket permits positioning of a source equidistant from the crystal faces and colinear with their common axis.

The coincidence circuit is of conventional design\* providing both single channel and coincidence outputs which

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\* Dwg. No. B-1547-A, file 6425, Laboratory for Nuclear Science, M.I.T., 28 April 1950.

# APPENDIX IV

## THE INSTRUMENTS

### 1. Introduction

#### 1.1. Introduction

This instrument consists of two main parts: a main body and a control panel. The main body is a rectangular box, approximately 10 inches long, 4 inches wide, and 2 inches deep. It is made of a light-colored material, possibly wood or plastic, and has a smooth finish. The control panel is a smaller rectangular box, approximately 4 inches long, 2 inches wide, and 1 inch deep. It is made of a darker material, possibly metal or plastic, and has a textured finish. The two parts are connected by a small metal rod, which is attached to the bottom of the main body and the top of the control panel. The control panel has a single switch and a small indicator light. The main body has a single input terminal and a single output terminal. The instrument is designed to be used in a laboratory setting, where it can be used to measure the resistance of a material. The control panel is used to adjust the current flowing through the material, and the main body is used to measure the voltage drop across the material. The instrument is simple in design and easy to use, and it provides accurate measurements of resistance.

The instrument is shown in the following diagram, which illustrates its basic components and their connections. The main body is connected to the control panel by a single wire, which carries the current flowing through the material. The control panel is connected to a power source, which provides the current. The main body is connected to a voltmeter, which measures the voltage drop across the material. The instrument is shown in a perspective view, which allows the viewer to see its three-dimensional shape and the relative positions of its components.

Science, N.I.T., 28 April 1950.



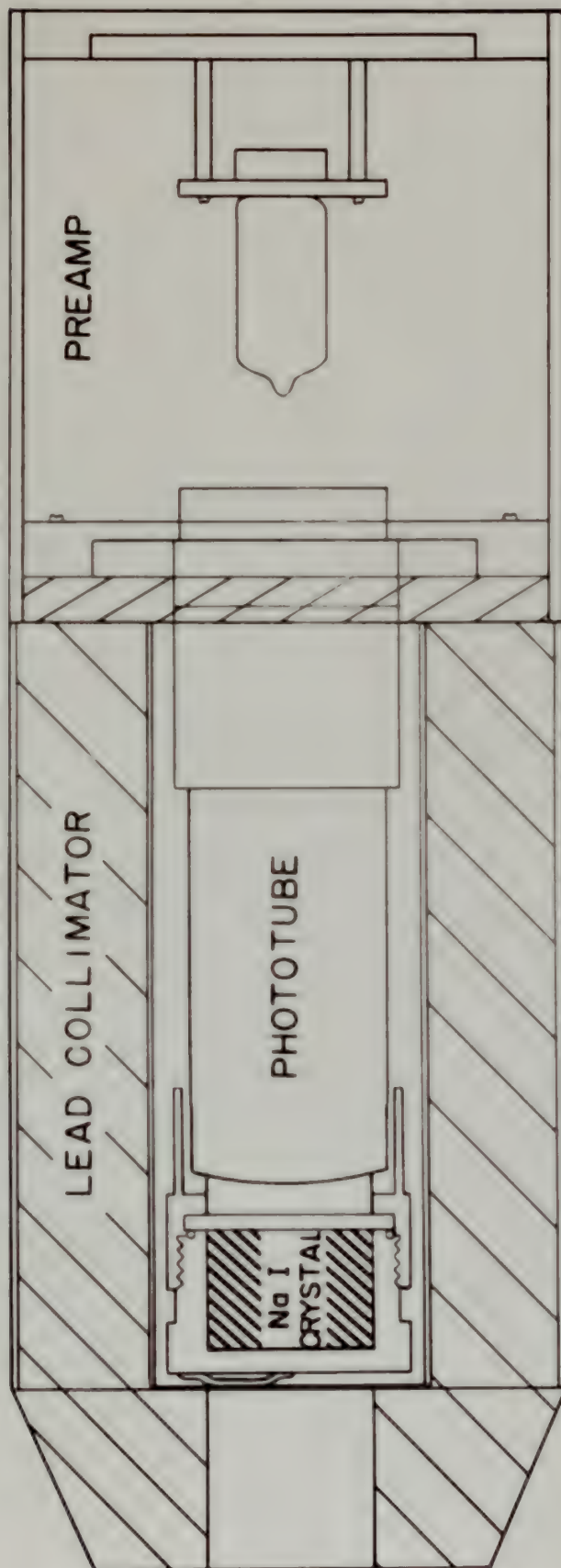
FIG. 1. Schematic diagram of vacuum tube assembly.

The design of vacuum tube assembly is shown in Fig. 1.

**Fig. 1. Schematic diagram of scintillation counter.**

The location of components within the lead shielding head is as indicate.







are fed through linear amplifiers\* to separate scaling circuits\*\*. The equipment assembled for normal use is illustrated in Fig. 2.

### B. Experimental Technique

The equipment is operated so that the individual channels register approximately equal counting rates when a source is at the mid-point on the axis between the counter heads.

Figure 3 illustrates that counting rates are only slightly affected by small displacements of the source from its central position. To minimize errors caused by variation in counter sensitivity due to other causes, a standard  $\text{Na}^{22}$  source was counted prior to each measurement and the correction thus determined was applied to the observed counting rate.

In all measurements the number of counts per 1 minute interval was recorded, each observation including at least three intervals for single channel counts and six intervals for coincidence counts. At least 10,000 events were included in each observation to insure a maximum fractional standard deviation of  $\leq 1$  percent.

---

\* Atomic Instrument Co. Model 204B Linear Amplifier.

\*\* Atomic Instrument Co. Model 1030 "Scale of 1000" Scaler.

and led through linear amplifiers to separate sealing  
 circuitry. The equipment assembled for several use is  
 illustrated in Fig. 2.

## 2. Experimental Techniques

The equipment is configured so that the individual  
 channels register approximately equal counting rates  
 over a range of the midpoint of the rate between  
 the counter heads.

Figure 3 illustrates that mounting bases are only  
 slightly offset by small displacements of the source  
 from its central position. To minimize errors caused by  
 variation in counter sensitivity due to other causes, a  
 standard  $^{22}\text{Na}$  source was mounted prior to each measure-  
 ment and the correction thus determined was applied to  
 the observed counting rate.

In all measurements the number of counts per 1  
 minute interval was recorded, and observations including  
 at least three independent single channel counts and  
 six intervals for coincidence counts. At least 10,000  
 events were included in each observation to insure a  
 maximum fractional standard deviation of  $\leq 1$  percent.

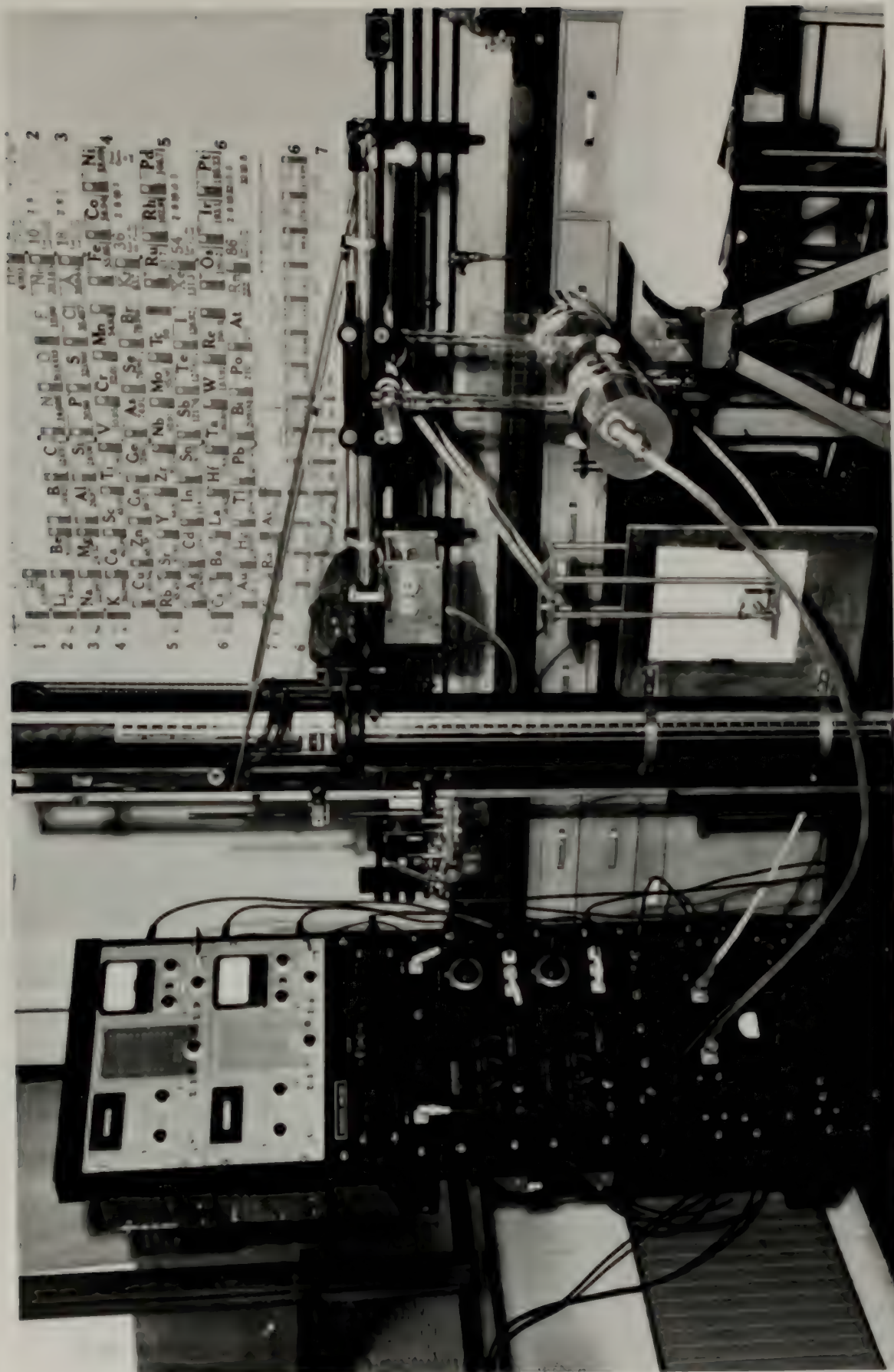
\* Ibmco Instrument Co. Model 1025 linear amplifier.  
 \*\* Ibmco Instrument Co. Model 1020 Model of 10000 Counter.





**Fig. 2. Coincidence counter assembly.**

The equipment is shown as assembled for use in scanning measurements at Massachusetts General Hospital. The scanning and plotting mechanisms are contained in the central section of the photograph. The opposing lead shielded counter heads are visible to the right of the plotting board.







SENSITIVITY DISTRIBUTION-COINCIDENCE COUNTS

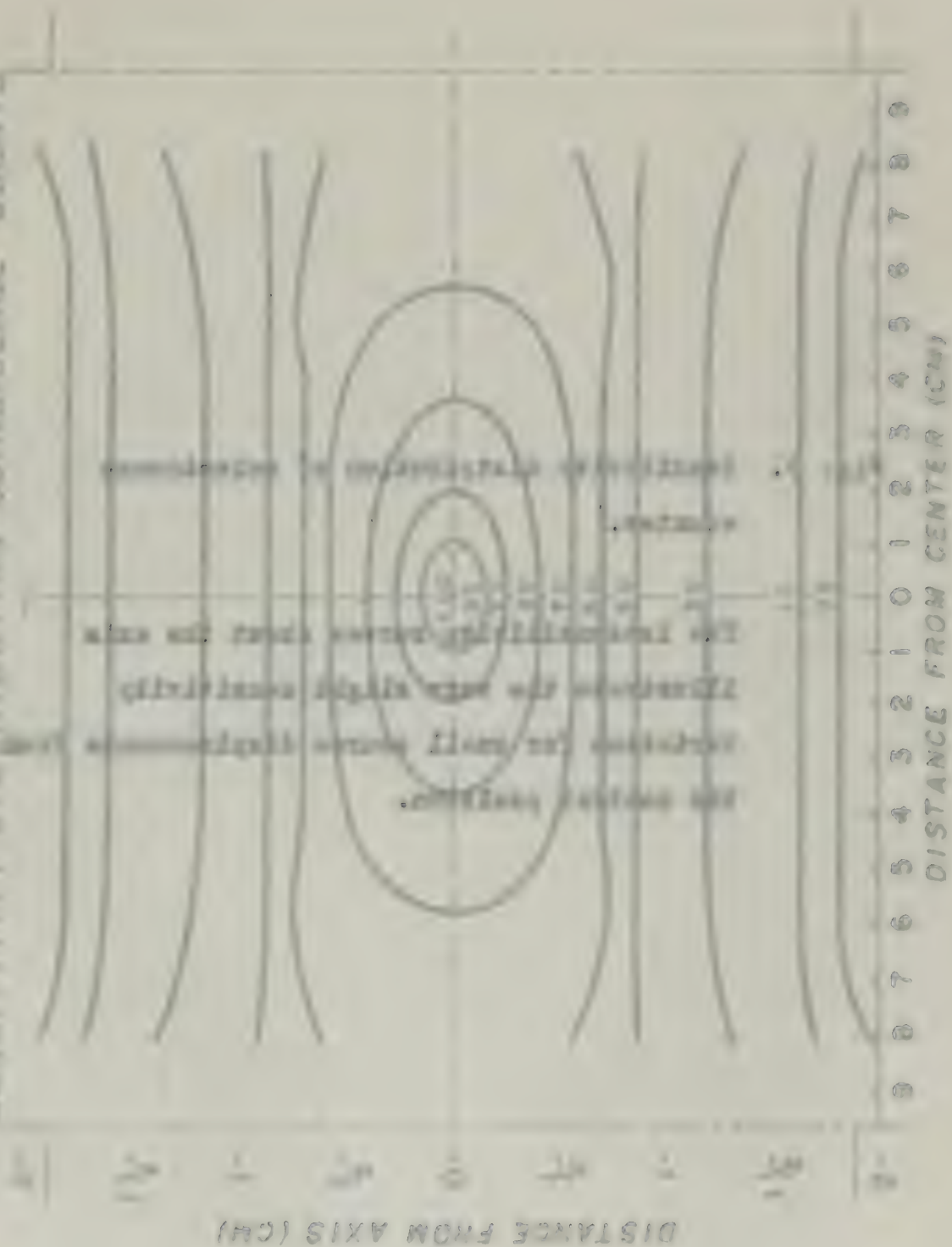
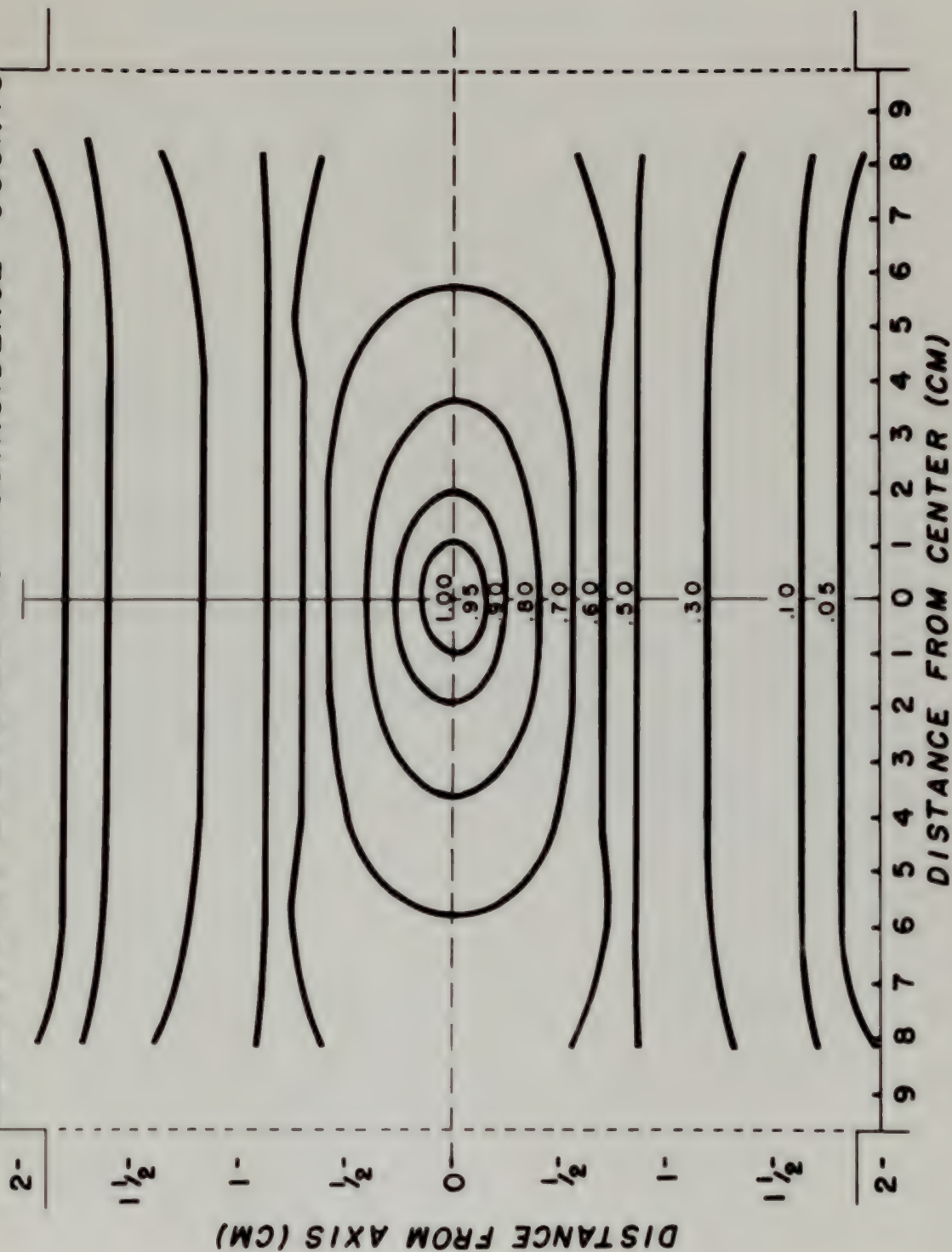


Fig. 3. Sensitivity distribution of coincidence counter.

The isosensitivity curves about the axis illustrate the very slight sensitivity variation for small source displacements from the central position.

# SENSITIVITY DISTRIBUTION-COINCIDENCE COUNTS







### C. Correction of Observed Counting Rates

Coincidence counting rates were corrected by subtracting from the observed values the chance coincidence rate. Chance rate was computed by means of the equation

$$C_{ch} = 2 \tau R_a R_b$$

where  $R_a$ ,  $R_b$  are the individual channel rates and  $\tau$  is the resolving time of the coincidence circuit. By counting an essentially monoenergetic  $\gamma$ -ray emitter positioned off the axis of the crystals,  $\tau$  was computed to be approximately 0.36  $\mu$ sec by use of the above equation.

Counter response appears to be linear for counting rates up to 140,000 cpm on single channels and 14,000 cpm for coincidences (Fig. 4). Consequently no corrections were applied to the data for resolving time losses.

## C. Correction of Observed Counting Rates

Counting rates were corrected by subtracting from the observed value the noise count rate. These rates were computed by means of the equation

$$C_{ch} = R - N_{ch}$$

where  $R$  is the individual channel rate and  $N$  is

the average rate of the coincidence circuit. By

assuming an essentially symmetric two-way circuit

positioned off the axis of the crystal,  $N$  was computed

to be approximately 0.36 cps by use of the above equation.

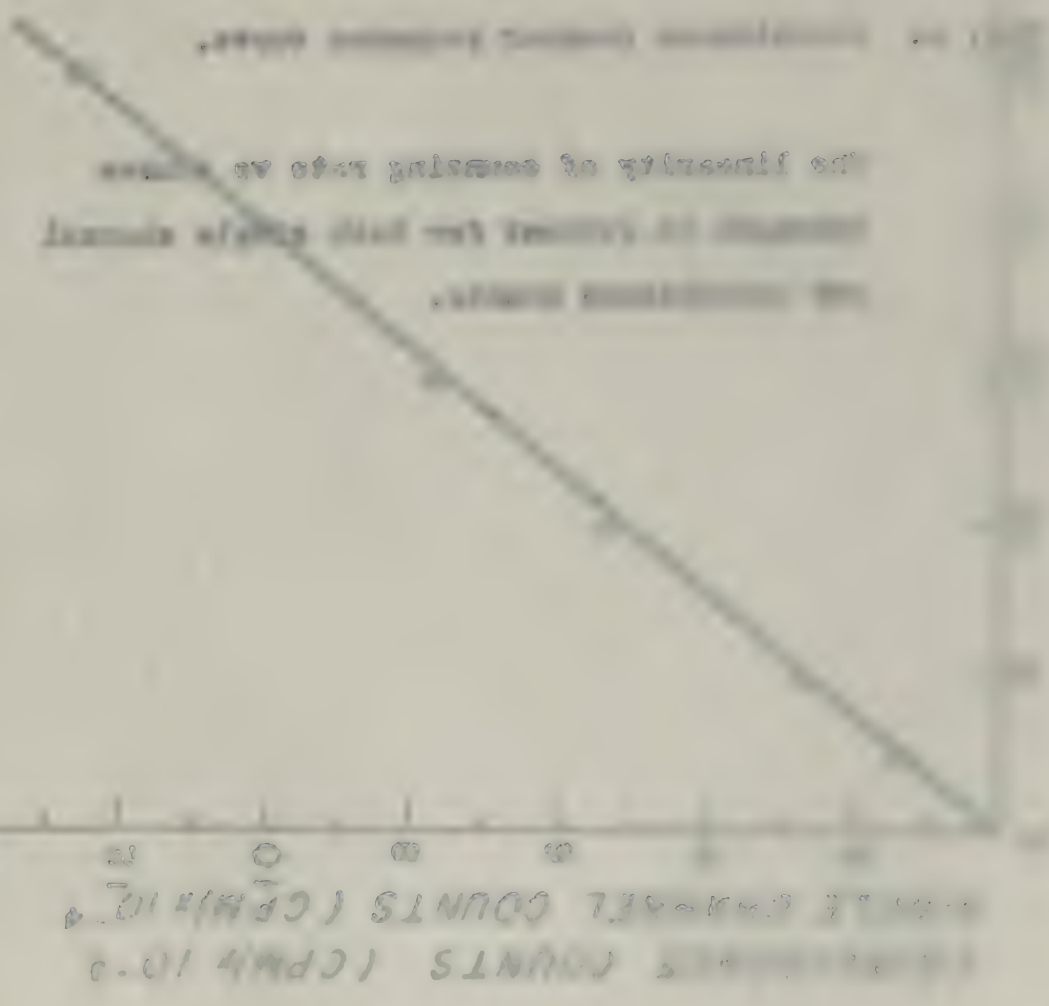
Counter response appears to be linear for counting

rates up to 140,000 cps on single channels and 14,000

cps for coincidences (Fig. 4). Consequently no corrections

were applied to the data for counting time losses.

CONCENTRATION  
COUNTS



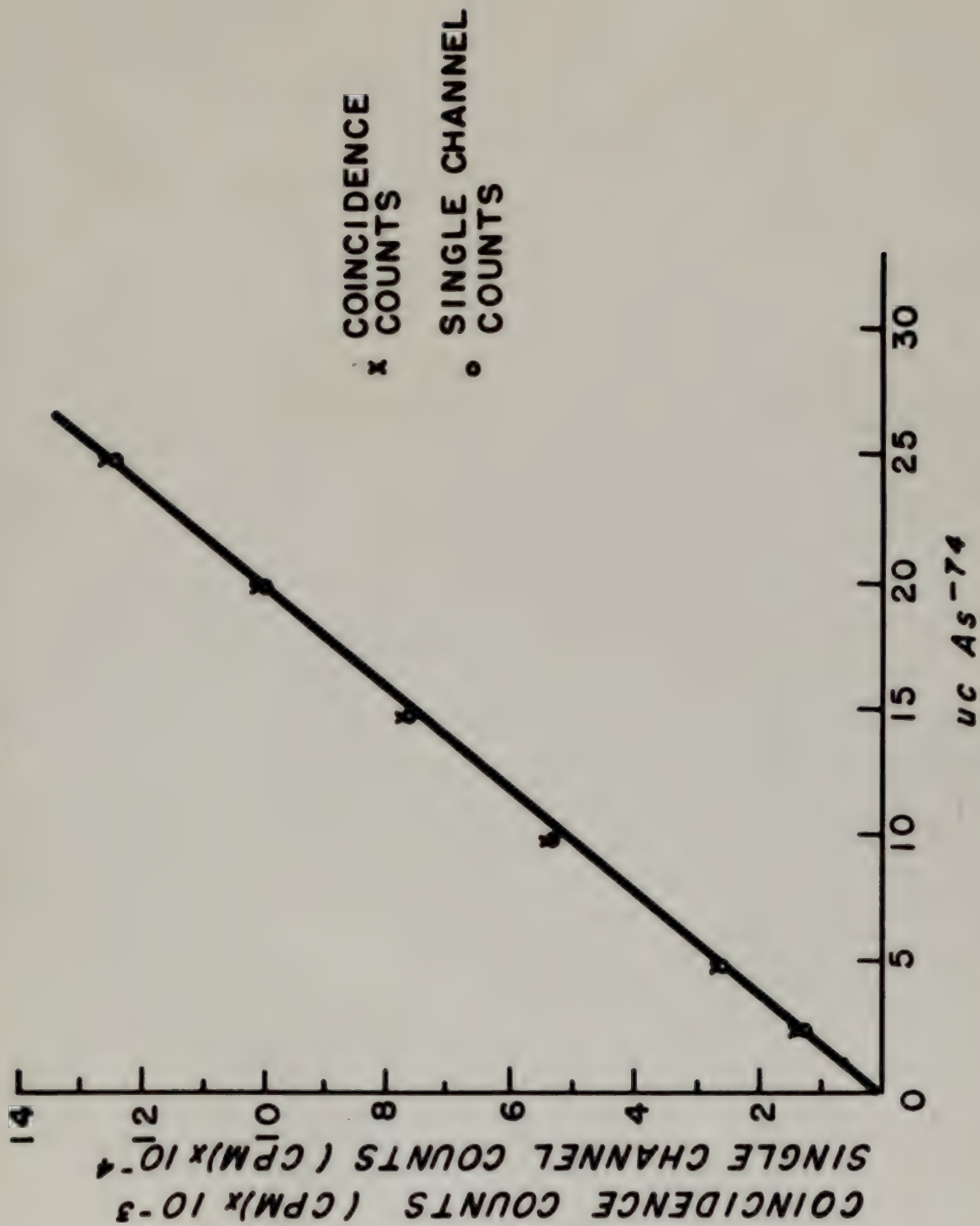
The linearity of counting rate vs. concentration is demonstrated by the straight line passing through the origin.

Figure 1: A graph showing the relationship between 'COUNTS (CPM) x 10^-3' (Y-axis) and 'COUNTS (CPM) x 10^-4' (X-axis).

Fig. 4. Coincidence counter response curve.

The linearity of counting rate vs source strength is evident for both single channel and coincidence counts.

















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An investigation of the  
radionuclides of arsenic  
produced by cyclotron bom-  
bardment of germanium with  
15 Mev deuterons.

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Watters

An investigation of the radio-  
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